

**BOW TIE** CONSTRUCTION

10 Downside  
Creascent

Construction  
Method Statement

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## 1.0 INTRODUCTION

1.1 This document has been prepared to identify the structural scheme and construction method statement at 10 Downside Crescent and is to be read in conjunction with ESI's Basement Impact Assessment report and SAS's report.

1.2 It is proposed to construct a new single storey extension with basement to the back of the existing semi detached property.

1.3 This report is in response to The Camden Development Policy DP27, with reference to paragraph 27.3., the proposed extension is a single storey at level with neighbouring properties.

1.4 Following the format guidance in The Camden Policy Guidance PG4, the stages for a Basement Impact Assessment are:

- o Stage 1 - Screening;
- o Stage 2 - Scoping;
- o Stage 3 - Site investigation and study;
- o Stage 4 - Impact assessment;
- o Stage 5 - Review and decision making.

ESI Consulting(ESI) have been commissioned to provide a Basement Impact Assessment report based on the above stages.

1.5 ESI's report follows the Flow Charts of Appendix E to The Camden Development Policy and Policy Guidance and uses the Figurative information given in the Camden Geological, Hydro-geological and Hydrological Study.

1.6 10 Downside Crescent is located on the relevant Figures of the Camden Geological, Hydro-geological and Hydrological Study, as part of ESI's report.

1.7 This section of the Basement Impact Assessment considers the structural proposals at 10 Downside Crescent and considers the potential sequencing of the works to ensure a safe sequence of works that maintains the stability of 10 Downside Crescent and all neighbouring structures at all times.

## 2.0 SITE INFORMATION

2.1 10 Downside Crescent is a Victorian property, three storey semi-detached build circa 1900. The construction is typical for buildings of this era with load bearing masonry walls and timber floors.

2.2 10 Downside Crescent lies within the generally sloped setting of Hampstead & Belsize Park, although the immediate area of the site is flat and level.

2.3 Site has front driveway which would be sufficient to accommodate skips and materials.

## 3.0 PROPOSED SCHEME – STRUCTURE

### 3.1 Groundwater

Based on SAS BIA report, we confirm that during investigation we found no groundwater or perched water present on the site. Two boreholes drilled to 15m in depth confirmed following build up: Made Ground extends down to depths 0.6 and 1.8m in thickness and resting on Head Deposit to depth 2.4 and 2.7m below ground level which sits on London Clay Formation. Over 4 weeks period water was observed on 2.24m and 1.86m depth, however this is not considered to represent a true groundwater level, rather rainwater trapped within the standpipes.

During construction, we are planning to continually monitor water levels in excavations and remove excess of water using pumps. Site size and excavations depth is very insignificant and would not affect local water table. Please refer to "Drainage" drawings and specifications for more details on future groundwater management.

3.2 Structural arrangement drawings, calculations and sequence is in the Appendix B.

## 4.0 CONSTRUCTION METHOD STATEMENT

4.1 This construction method statement describes how the works can proceed safely while minimising the impact of the works.

4.2 All of the underpinning works are to be carried out by a competent foundation contractor who is familiar with the suggested proposals. Works will be executed to comply with the Considerate Contractors Scheme.

4.3 Bow Tie Construction (BTC) have prepared an outline construction and temporary works sequence to validate that these works are achievable, BTC is going to submit full proposals, method statement and calculations to the Structural Engineer for review prior to the start of any works on site that demonstrate how the works can proceed safely while minimising the impact on adjoining properties. These proposals will all be agreed as safe working methods with the party wall surveyors and checking engineers as part of the party wall process, prior to any of the works commencing.

4.4 BTC is responsible for the design and erection of all temporary works in accordance with all relevant British Standards. BTC is to provide adequate supervision to ensure that the stability of the existing structure, excavations and surrounding structures are maintained at all times.

4.5 It is assumed deliveries, removals and access for operatives will take place from Downside Crescent. This access point is to be managed and controlled in such a way to ensure the safety to site operatives and the general public at all times.

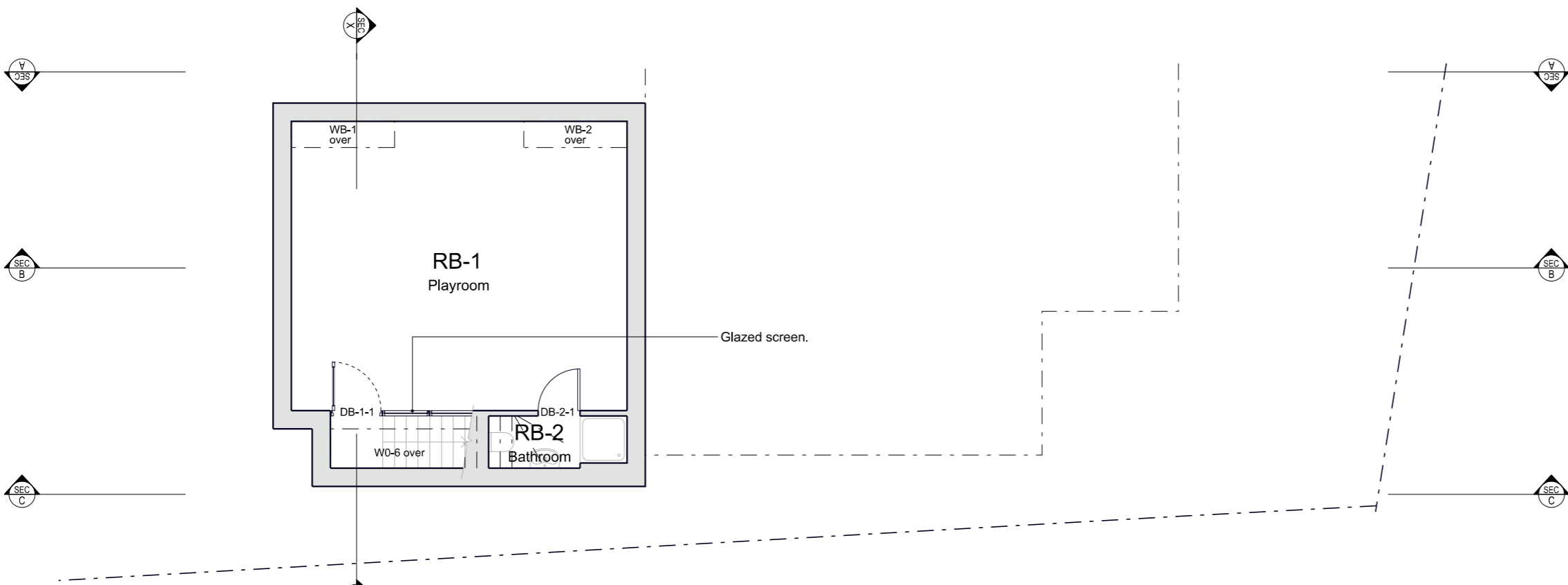
4.6 At this stage the exact construction sequence has not been established, however, below is a suggested construction sequence for the works (refer to Appendix A for sketches).

- Mobilisation and site set up. Fully enclosed site hoarding to the front of the property is not required as all main works take place at the back of the property. Temporary light weight timber frame site office and welfare facility will be constructed at the back garden.
- Commence underpinning of existing back wall in 1m bays following agreed sequence detailed in Appendix B.
- Complete existing property underpinning
- Commence construction of retaining walls for the basement as per Appendix B
- Commence reduce level dig to formation level, installing temporary horizontal propping at top of retaining walls.
- Excavate to basement formation level and install lateral props at base of retaining walls.

- Place blinding and reinforcement to basement slab. Cast basement slab and internal load bearing rc wall elements.
- Place formwork and reinforcement for ground floor slab. Cast ground floor slab.
- Remove all temporary props and make good.
- Commence works to upper floors and internal fit out.

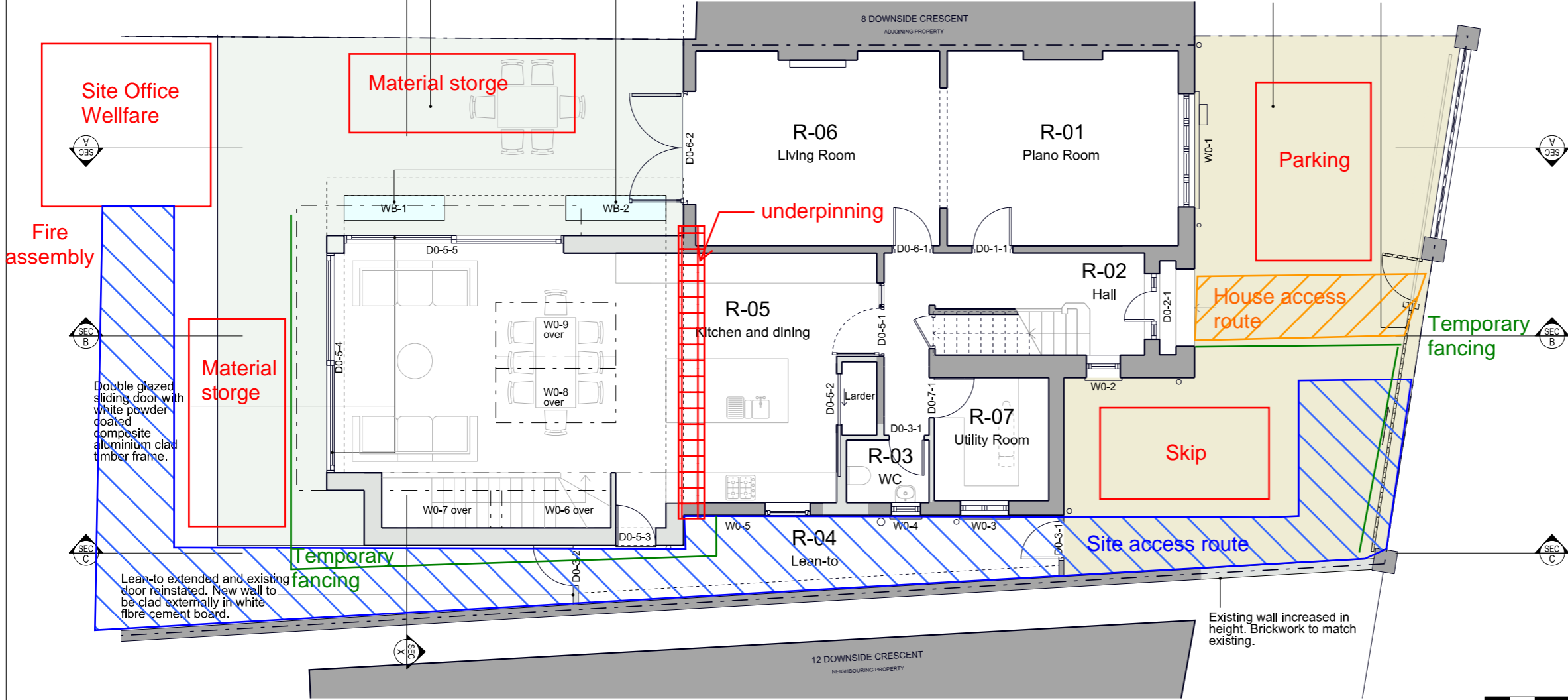
# 10 Downside Creascent

## Appendix A



Proposed Basement Plan

Patio to be surfaced in grey reconstituted stone slabs.  
Walk-on skylights.  
Driveway resurfaced in permeable buff coloured resin bound gravel.  
New black powder coated steel motorised sliding gate to match pattern of existing railing.



Proposed Ground Floor Plan

Drawings may be scaled for purposes of Planning.  
Any discrepancies should be reported immediately to the designer.  
If in doubt ask.  
This drawing is copyright of the designer.  
These drawings are based on survey plans provided by the client.  
The designer accepts no liability for inaccuracies.  
Check all dimensions on site before proceeding with the works.

Drawing Status:

Revision	Date

**BOW TIE CONSTRUCTION**  
Bow Tie Construction Ltd, Unit 86, Cressex Enterprise Centre, Lincoln Road, High Wycombe, Bucks, HP12 3RL. info@bowtieconstruction.co.uk

Project: 10 Downside Crescent Belsize Park NW3 2AP

Drawing: Proposed Ground Floor and Basement Plans

Scale: 1:100 @ A3	Date: June 2016
Drng. no. 129 P 00	Revision -

# 10 Downside Creascent

## Appendix B



# **Structural Calculations**

**for new basement at**

**10, Downside Crescent  
Belsize Park, London  
NW3 2AP**

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October 2016

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

<b>Rev</b>	<b>Date</b>	<b>Notes</b>
-	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 <sup>2</sup>
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 <sup>2</sup>
Typical imposed loads on floors	1.50 kN/m <sup>2</sup>
Partitions loads on floors (as imposed loads)	1.00 kN/m <sup>2</sup>
Typical imposed loads on flat roofs allowing for maintenance	1.50 kN/m <sup>2</sup>

## 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.

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Job title: 10 Downside Crescent				
Calculations: Area loads	Designed: ab	Date: 11/10/2016	Ckd: -	

Existing pitched roof

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

Existing typical floor

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

External brick wall

Dead	External render		0.60 kN/m <sup>2</sup>
	215mm brickwork		4.73 kN/m <sup>2</sup>
	Plaster		0.25 kN/m <sup>2</sup>
			<hr/> 5.58 kN/m <sup>2</sup>

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Calculations: Area loads	Designed: ab	Date: 11/10/2016	Ckd: -

Proposed ground floor slab

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

Proposed basement floor slab

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

Proposed flat roof

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

Glazing

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

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Job title: 10 Downside Crescent				
Calculations: Area loads		Designed:    ab	Date:           11/10/2016	Ckd:           -

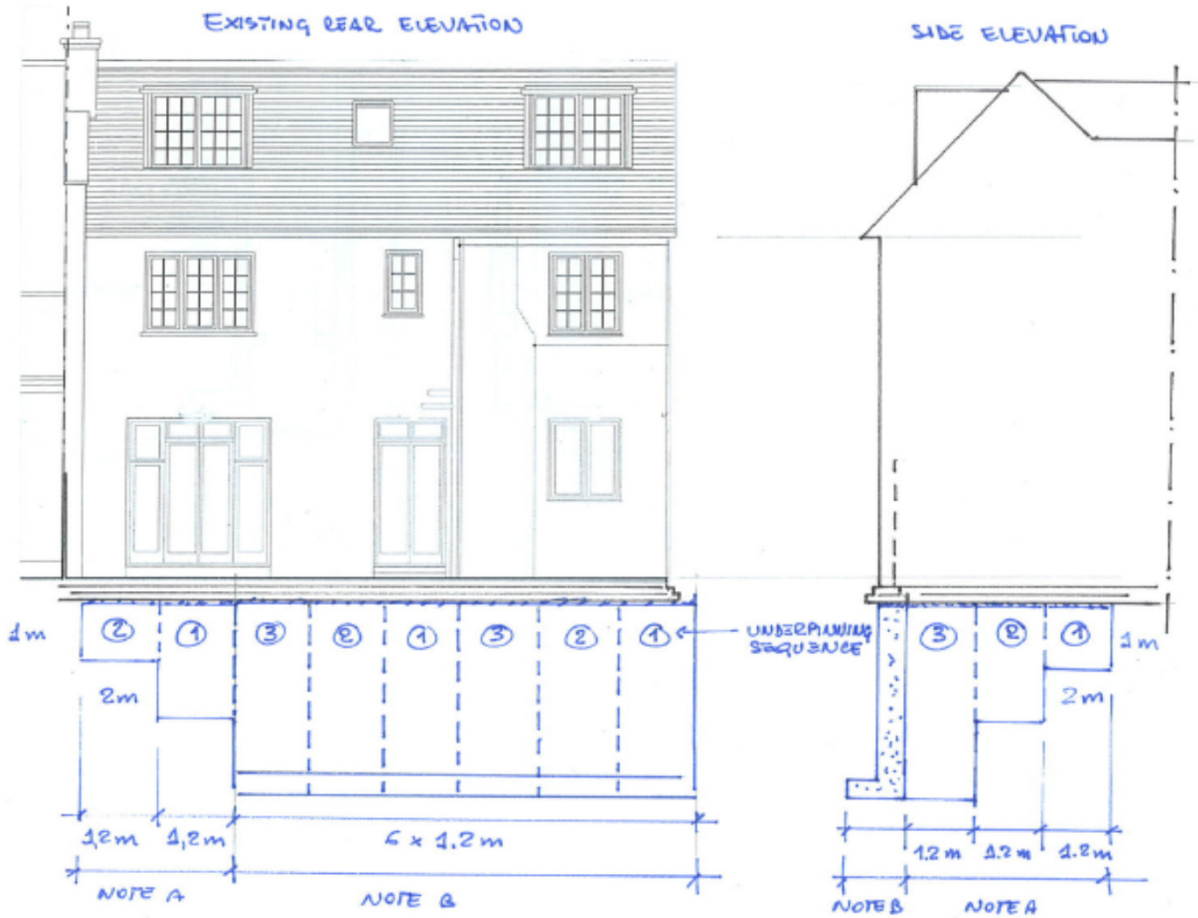
Proposed external wall

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



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

Beam & Load description	Span mm	Area loads		Width mm	Location		UDL		Point loads	
		DL kN/m <sup>2</sup>	LL kN/m <sup>2</sup>		from mm	to mm	DL kN/m	LL kN/m	DL kN	LL kN
<b>Phase 1 - underpinning of existing building back wall</b>										

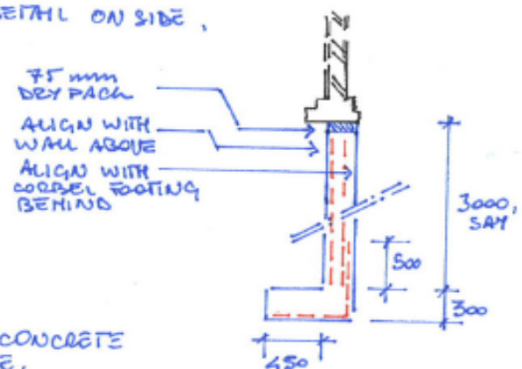


NOTE A : UNDERPIN EXISTING CORBEL FOOTING FOR THE WHOLE WIDTH USING C30 MASS CONCRETE. PINS HAVE TO BE 1.2m LONG MAXIMUM. DRY PACK BETWEEN TOP OF PINS AND BOTTOM SURFACE OF CORBEL FOOTING WITH 1:3 CEMENT: SAND BEDDING, 75mm DEEP.

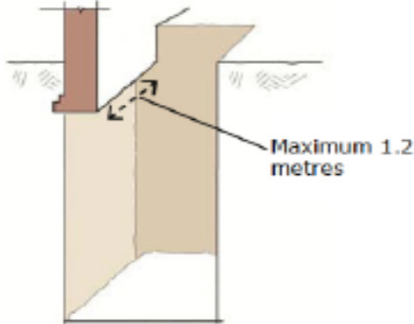
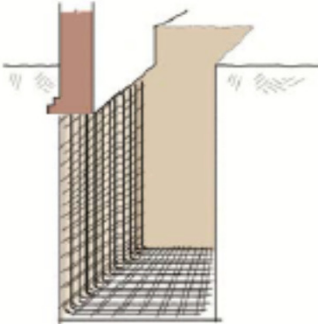
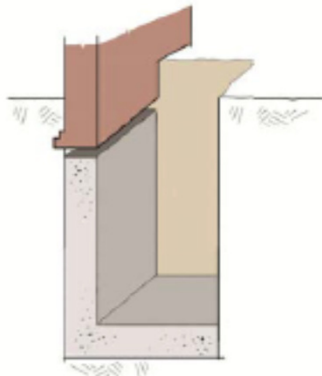
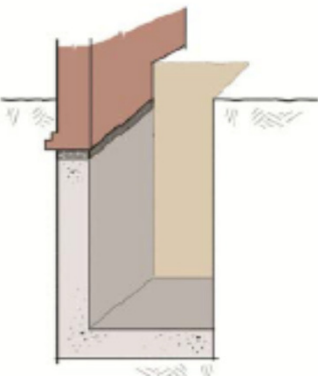
NOTE B: UNDERPIN EXISTING BACK WALL AS FOR DETAIL ON SIDE, USING C30 RC WALL WITH C503 MESH ON TOP WALL AND STEM ( $\phi 8 @ 100$  c/c AS VERTICAL).

NOTE 1: CONNECT PINS USING  $\phi 16$  DOWEL BARS @ 300 c/c PLACED IN THE MIDDLE LINE OF WALL WIDTH. USE 500mm LONG BARS REIN ANCHORED FOR 250mm IN EACH PIN.

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



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

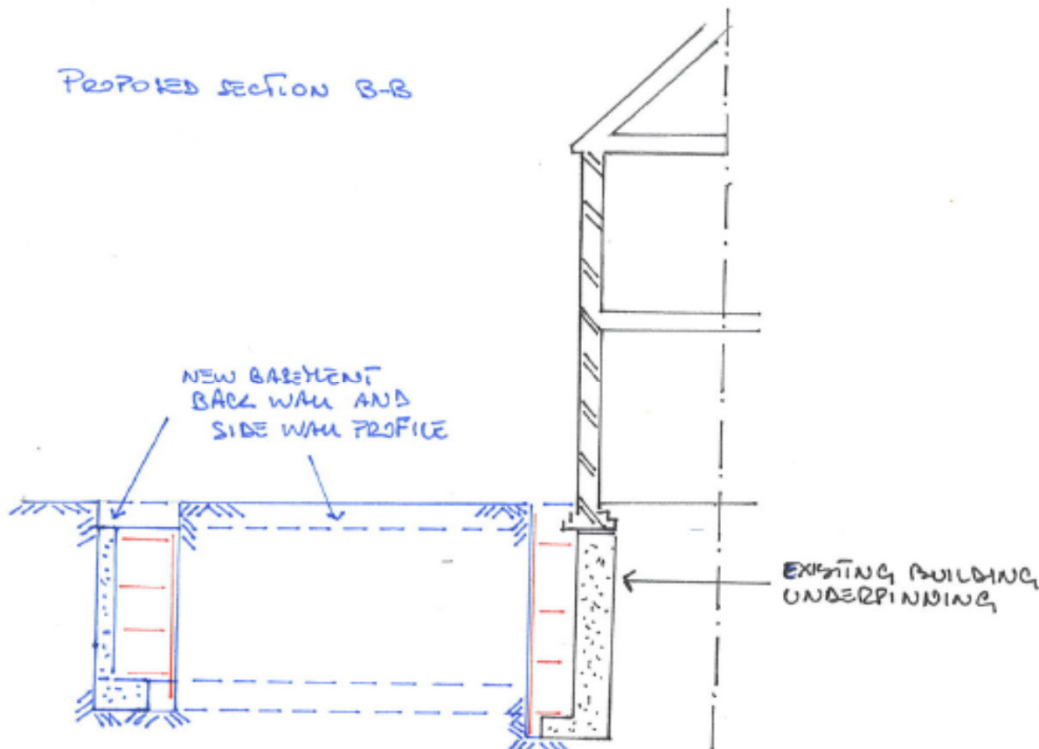
Beam & Load description	Span mm	Area loads		Width mm	Location		UDL		Point loads	
		DL kN/m <sup>2</sup>	LL kN/m <sup>2</sup>		from mm	to mm	DL kN/m	LL kN/m	DL kN	LL kN
<div style="display: flex; justify-content: space-around;"> <div style="width: 45%;">  <p style="text-align: center;"><b>Maximum 1.2 metres</b></p> <ol style="list-style-type: none"> <li>Excavation must be fully supported by props and shoring.</li> <li>Edge protection to prevent falls into the excavation must be installed.</li> <li>A temporary vertical prop or support may be placed under the wall to keep any loose bricks or masonry in place.</li> <li>The main load from the existing wall will span onto the wall and foundations on either side of the excavation.</li> </ol> <p style="text-align: center;"><b><u>Stage 1. Excavation</u></b></p> </div> <div style="width: 45%;">  <ol style="list-style-type: none"> <li>Reinforcement is fixed into position.</li> <li>Reinforcement details are given in the engineering design.</li> </ol> <p style="text-align: center;"><b><u>Stage 2. Reinforcement</u></b></p> </div> </div>										
<div style="display: flex; justify-content: space-around;"> <div style="width: 45%;">  <ol style="list-style-type: none"> <li>Concrete is placed in the toe first.</li> <li>Once the toe is sufficiently cured the concrete wall is poured.</li> <li>Shuttering, usually timber, is used to hold the concrete for the wall in place while it is placed.</li> <li>Gap of approximately 75mm left between the top of the concrete and the underside of the existing foundation.</li> </ol> <p style="text-align: center;"><b><u>Stage 3. Concrete placement</u></b></p> </div> <div style="width: 45%;">  <ol style="list-style-type: none"> <li>After a minimum of 24 hours dry-pack is rammed into the 75mm void that has been left above the new underpin.</li> <li>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.</li> <li>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.</li> </ol> <p style="text-align: center;"><b><u>Stage 4. Dry packing</u></b></p> </div> </div>										

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Beam & Load description	Span mm	Area loads		Width mm	Location		UDL		Point loads	
		DL kN/m <sup>2</sup>	LL kN/m <sup>2</sup>		from mm	to mm	DL kN/m	LL kN/m	DL kN	LL 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

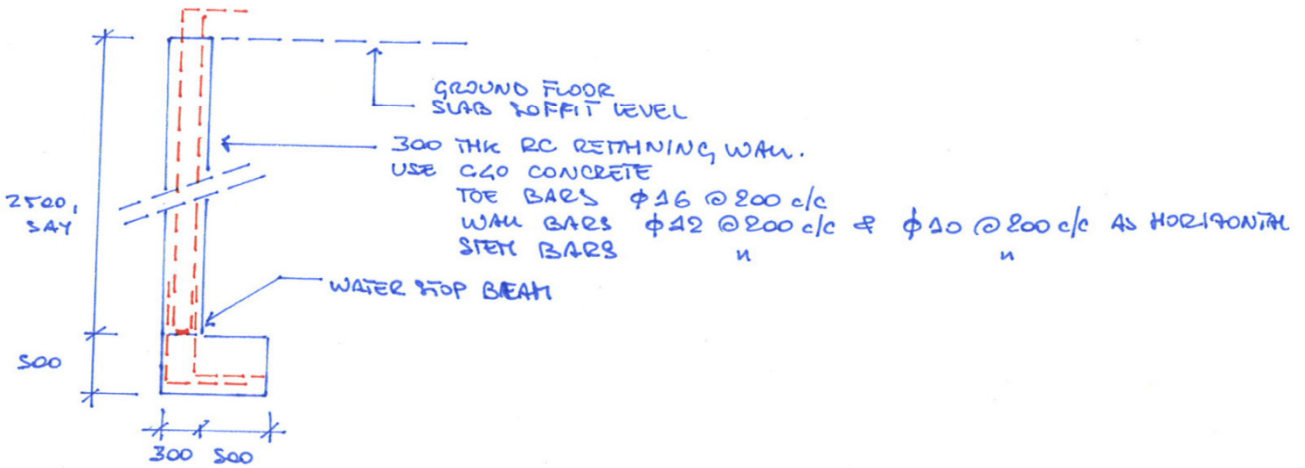
**Phase 2 - new basement back and side walls cast in place**



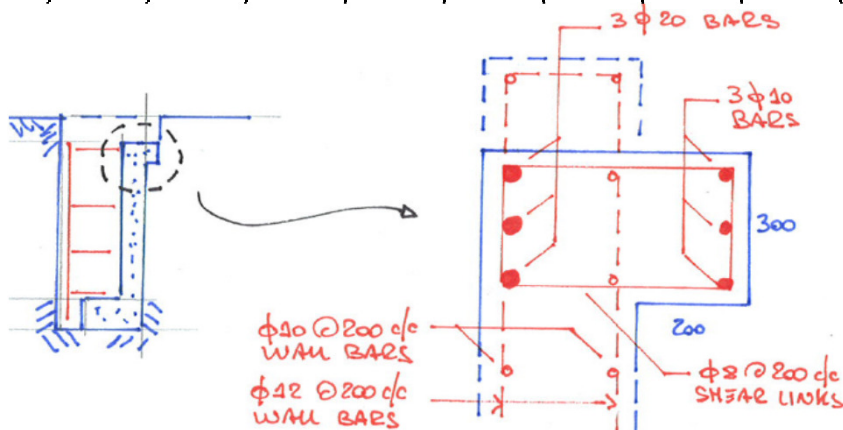
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Calculations:	Loads on elements & constr. sequence	Designed: ab	Date: 11/10/2016	Ckd: -

Beam & Load description	Span mm	Area loads		Width mm	Location		UDL		Point loads	
		DL kN/m <sup>2</sup>	LL kN/m <sup>2</sup>		from mm	to mm	DL kN/m	LL kN/m	DL kN	LL 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.

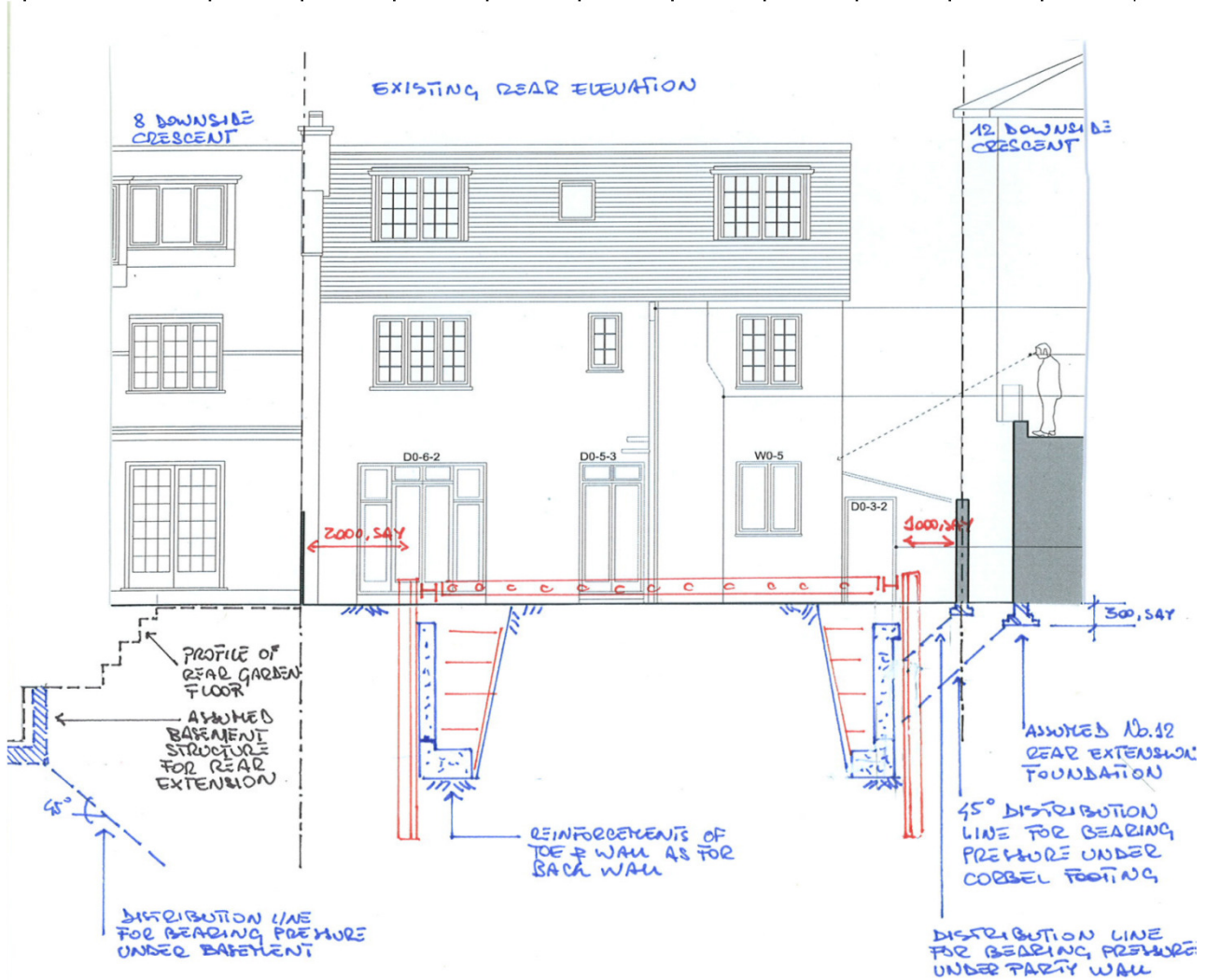


<u>Load on back retaining wall</u>										
Ground floor		6.35	2.50	3200			20.32	8.00		
		See Sheet 5.2 for basement back retaining wall calculations								
<u>Load on side wall top beam ( see sheet 5.4 )</u>										
		See Sheet 5.3 and 5.4B for basement side wall and top beam calculations								



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Job title:		10 Downside Crescent		
Calculations:		Designed: ab	Date: 11/10/2016	Ckd: -

Beam & Load description	Span mm	Area loads		Width mm	Location		UDL		Point loads	
		DL kN/m <sup>2</sup>	LL kN/m <sup>2</sup>		from mm	to mm	DL kN/m	LL kN/m	DL kN	LL kN



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

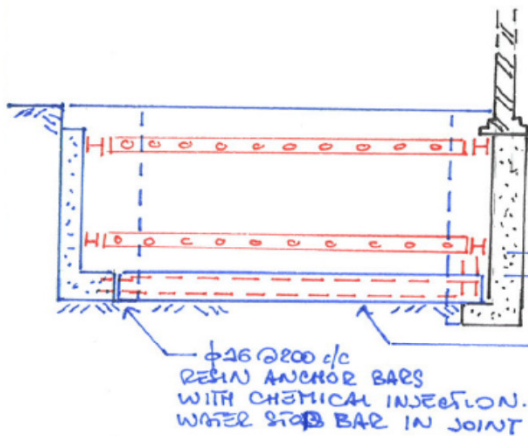
It is assumed that loads from No.8 Downside Crescent rear basement foundation do not affect No. 10 proposed basement walls, due to distance ( bigger than 7m ) and bearing level. This is valid even for the opposite.

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 extension does not affect new basement wall due to distance ( distribution line of load from No. 2 rear extension corbel footing intercepts only new basement slab, which is placed more than 2m far in plan ).

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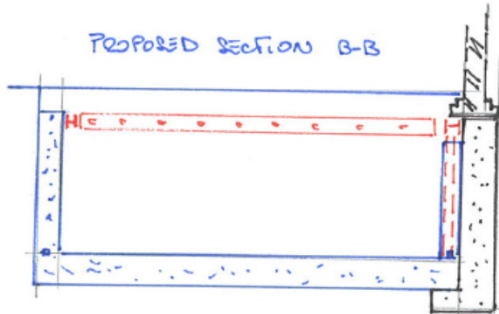
Beam & Load description	Span mm	Area loads		Width mm	Location		UDL		Point loads	
		DL kN/m <sup>2</sup>	LL kN/m <sup>2</sup>		from mm	to mm	DL kN/m	LL kN/m	DL kN	LL kN
<b>Phase 3 - new basement front wall and slab cast in place</b>										

PROPOSED SECTION B-B



- LOWER EXCAVATION WITHIN BASEMENT AREA IN ORDER TO PLACE TOP TEMPORARY WALKING BEAMS & PROPS.
- LOWER EXCAVATION AGAIN TO PLACE BOTTOM PROPS.
- LOWER AGAIN EXCAVATION, PLACE REINFORCEMENT AND CAST 300 mm THK BASEMENT SLAB.

PROPOSED SECTION B-B

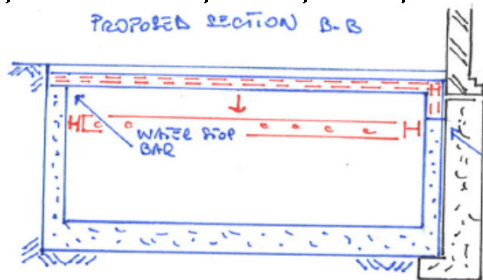


- REMOVE BOTTOM HORIZONTAL PROPS AND CAST BASEMENT FRONT WALL
- USE C40 CONCRETE FOR 300 mm THK WALL AND  $\phi 26 @ 200$  c/c BARS (INSIDE AND OUTSIDE FACE),  $\phi 20 @ 200$  c/c HORIZONTAL BARS (INSIDE AND OUTSIDE FACE)

<b>Phase 4 - new ground floor slab cast in place</b>										
Load on new extension ground floor slab										
Ground floor	6400x3500	6.35	2.50	1000			6.35	2.50		
See Sheet 5.5 for ground floor slab calculations										

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

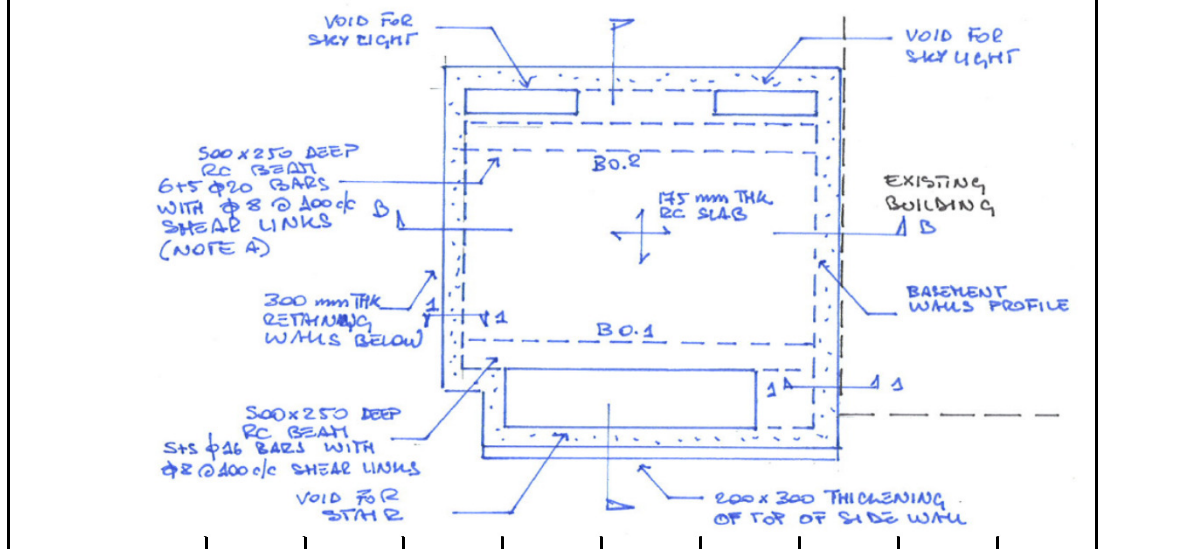
Beam & Load description	Span mm	Area loads		Width mm	Location		UDL		Point loads	
		DL kN/m <sup>2</sup>	LL kN/m <sup>2</sup>		from mm	to mm	DL kN/m	LL kN/m	DL kN	LL kN



- PROP AGAIN REINFORCING WALL AT LOWER LEVEL AND REMOVE TOP PROPS.
- CAST GROUND FLOOR SLAB 175 mm THICK. USE C40 CONCRETE,  $\phi 12 @ 200$  o/c BARS AT TOP AND BOTTOM IN BOTH DIRECTIONS.

<u>Beam B0.1</u>										
	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		
<u>Beam B0.2</u>										
	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										

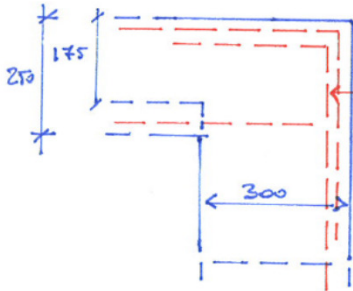
PROPOSED GROUND FLOOR PLAN



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

Beam & Load description	Span mm	Area loads		Width mm	Location		UDL		Point loads	
		DL kN/m <sup>2</sup>	LL kN/m <sup>2</sup>		from mm	to mm	DL kN/m	LL kN/m	DL kN	LL kN

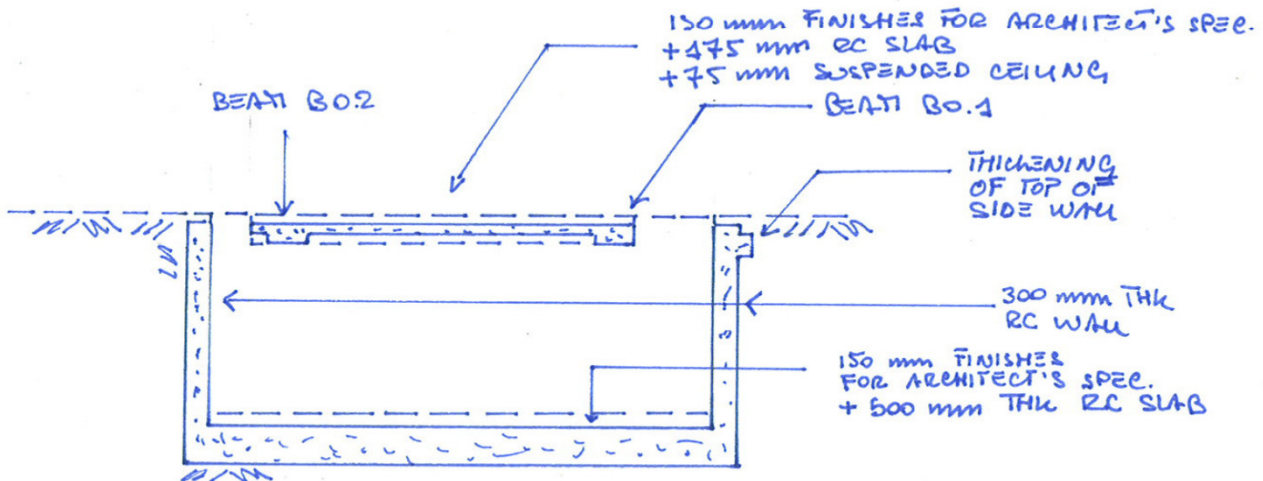
Sec. 1-1



PROVIDE  
 S  $\phi$  16 @ 400 c/c  
 STARTING BARS  
 FOR SLAB THICKENING  
 (SAY 900 mm OVERLAP)

NOTE A: PROVIDE 6  $\phi$  20  
 STARTING BARS INTO  
 RETAINING WALL TO  
 GUARANTEE MOMENT  
 CONNECTION (SAY 1000 mm  
 OVERLAP)

PROPOSED TRANSVERSE SECTION



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

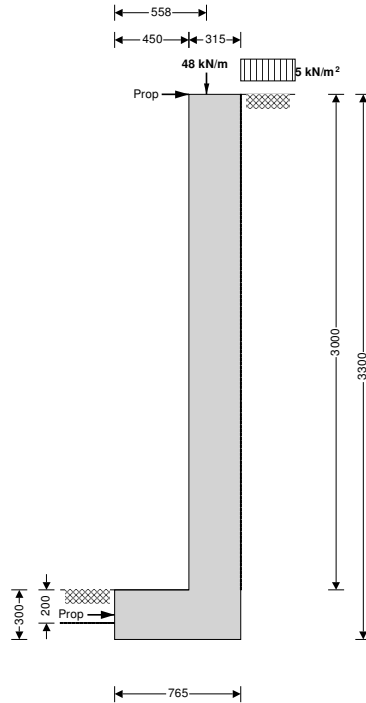
Phase 6 - build up back extension ground floor walls and flat roof



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**RETAINING WALL ANALYSIS (BS 8002:1994)**

TEDDS calculation version 1.2.01.06



**Wall details**

- Retaining wall type
- Height of retaining wall stem
- Thickness of wall stem
- Length of toe
- Length of heel
- Overall length of base
- Thickness of base
- Depth of downstand
- Position of downstand
- Thickness of downstand
- Height of retaining wall
- Depth of cover in front of wall
- Depth of unplanned excavation
- Height of ground water behind wall
- Height of saturated fill above base
- Density of wall construction
- Density of base construction
- Angle of rear face of wall
- Angle of soil surface behind wall
- Effective height at virtual back of wall

**Cantilever propped at both**

- $h_{stem} = 3000$  mm
- $t_{wall} = 315$  mm
- $l_{toe} = 450$  mm
- $l_{heel} = 0$  mm
- $l_{base} = l_{toe} + l_{heel} + t_{wall} = 765$  mm
- $t_{base} = 300$  mm
- $d_{ds} = 0$  mm
- $l_{ds} = 15$  mm
- $t_{ds} = 300$  mm
- $h_{wall} = h_{stem} + t_{base} + d_{ds} = 3300$  mm
- $d_{cover} = 0$  mm
- $d_{exc} = 200$  mm
- $h_{water} = 0$  mm
- $h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0 \text{ mm}) = 0$  mm
- $\gamma_{wall} = 23.6$  kN/m<sup>3</sup>
- $\gamma_{base} = 23.6$  kN/m<sup>3</sup>
- $\alpha = 90.0$  deg
- $\beta = 0.0$  deg
- $h_{eff} = h_{wall} + l_{heel} \times \tan(\beta) = 3300$  mm

**Retained material details**

- Mobilisation factor  
 $M = 1.5$
- Moist density of retained material  
 $\gamma_m = 18.0$  kN/m<sup>3</sup>

Project <b>10 Downside Crescent</b>				Job no. <b>1411</b>	
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Saturated density of retained material  $\gamma_s = 21.0 \text{ kN/m}^3$   
 Design shear strength  $\phi' = 18.6 \text{ deg}$   
 Angle of wall friction  $\delta = 0.0 \text{ deg}$

**Base material details**

Firm clay  
 Moist density  $\gamma_{mb} = 18.0 \text{ kN/m}^3$   
 Design shear strength  $\phi'_b = 16.5 \text{ deg}$   
 Design base friction  $\delta_b = 18.6 \text{ deg}$   
 Allowable bearing pressure  $P_{\text{bearing}} = 100 \text{ kN/m}^2$

**Using Coulomb theory**

Active pressure coefficient for retained material

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

Passive pressure coefficient for base material

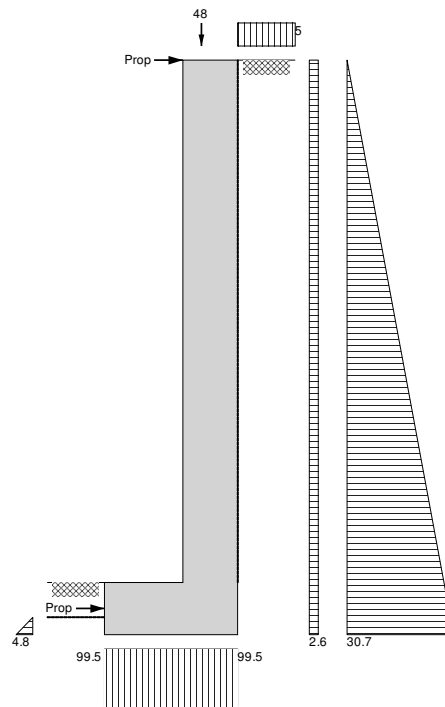
$$K_p = \sin(90 - \phi'_b)^2 / (\sin(90 - \delta_b) \times [1 - \sqrt{(\sin(\phi'_b + \delta_b) \times \sin(\phi'_b) / (\sin(90 + \delta_b)))]^2) = 2.835$$

**At-rest pressure**

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

**Loading details**

Surcharge load on plan Surcharge = **5.0 kN/m<sup>2</sup>**  
 Applied vertical dead load on wall  $W_{\text{dead}} = 41.0 \text{ kN/m}$   
 Applied vertical live load on wall  $W_{\text{live}} = 7.4 \text{ kN/m}$   
 Position of applied vertical load on wall  $l_{\text{load}} = 558 \text{ mm}$   
 Applied horizontal dead load on wall  $F_{\text{dead}} = 0.0 \text{ kN/m}$   
 Applied horizontal live load on wall  $F_{\text{live}} = 0.0 \text{ kN/m}$   
 Height of applied horizontal load on wall  $h_{\text{load}} = 0 \text{ mm}$



Loads shown in kN/m, pressures shown in kN/m<sup>2</sup>

Project		10 Downside Crescent		Job no.		1411	
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ab	12/10/2016						

### Vertical forces on wall

Wall stem	$W_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall} = 22.3 \text{ kN/m}$
Wall base	$W_{base} = l_{base} \times t_{base} \times \gamma_{base} = 5.4 \text{ kN/m}$
Applied vertical load	$W_v = W_{dead} + W_{live} = 48.4 \text{ kN/m}$
Total vertical load	$W_{total} = W_{wall} + W_{base} + W_v = 76.1 \text{ kN/m}$

### Horizontal forces on wall

Surcharge	$F_{sur} = K_a \times \text{Surcharge} \times h_{eff} = 8.5 \text{ kN/m}$
Moist backfill above water table	$F_{m\_a} = 0.5 \times K_a \times \gamma_m \times (h_{eff} - h_{water})^2 = 50.6 \text{ kN/m}$
Total horizontal load	$F_{total} = F_{sur} + F_{m\_a} = 59.1 \text{ kN/m}$

### Calculate total propping force

Passive resistance of soil in front of wall	$F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb} = 0.2 \text{ kN/m}$
Propping force	$F_{prop} = \max(F_{total} - F_p - (W_{total} - W_{live}) \times \tan(\delta_b), 0 \text{ kN/m})$ $F_{prop} = 35.8 \text{ kN/m}$

### Overturning moments

Surcharge	$M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2 = 14.1 \text{ kNm/m}$
Moist backfill above water table	$M_{m\_a} = F_{m\_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3 = 55.7 \text{ kNm/m}$
Total overturning moment	$M_{ot} = M_{sur} + M_{m\_a} = 69.7 \text{ kNm/m}$

### Restoring moments

Wall stem	$M_{wall} = W_{wall} \times (l_{toe} + t_{wall} / 2) = 13.5 \text{ kNm/m}$
Wall base	$M_{base} = W_{base} \times l_{base} / 2 = 2.1 \text{ kNm/m}$
Design vertical dead load	$M_{dead} = W_{dead} \times l_{load} = 22.9 \text{ kNm/m}$
Total restoring moment	$M_{rest} = M_{wall} + M_{base} + M_{dead} = 38.5 \text{ kNm/m}$

### Check bearing pressure

Total vertical reaction	$R = W_{total} = 76.1 \text{ kN/m}$
Distance to reaction	$X_{bar} = l_{base} / 2 = 383 \text{ mm}$
Eccentricity of reaction	$e = \text{abs}((l_{base} / 2) - X_{bar}) = 0 \text{ mm}$

**Reaction acts within middle third of base**

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

**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	$F_{prop\_top} = (M_{ot} - M_{rest} + R \times l_{base} / 2 - F_{prop} \times t_{base} / 2) / (h_{stem} + t_{base} / 2) = 17.460 \text{ kN/m}$
Propping force to base of wall	$F_{prop\_base} = F_{prop} - F_{prop\_top} = 18.299 \text{ kN/m}$



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**RETAINING WALL DESIGN (BS 8002:1994)**

TEDDS calculation version 1.2.01.06

**Ultimate limit state load factors**

Dead load factor  $\gamma_{f,d} = 1.4$   
Live load factor  $\gamma_{f,l} = 1.6$   
Earth and water pressure factor  $\gamma_{f,e} = 1.4$

**Factored vertical forces on wall**

Wall stem  $W_{wall,f} = \gamma_{f,d} \times h_{stem} \times t_{wall} \times \gamma_{wall} = 31.2 \text{ kN/m}$   
Wall base  $W_{base,f} = \gamma_{f,d} \times l_{base} \times t_{base} \times \gamma_{base} = 7.6 \text{ kN/m}$   
Applied vertical load  $W_{v,f} = \gamma_{f,d} \times W_{dead} + \gamma_{f,l} \times W_{live} = 69.2 \text{ kN/m}$   
Total vertical load  $W_{total,f} = W_{wall,f} + W_{base,f} + W_{v,f} = 108 \text{ kN/m}$

**Factored horizontal at-rest forces on wall**

Surcharge  $F_{sur,f} = \gamma_{f,l} \times K_0 \times \text{Surcharge} \times h_{eff} = 18 \text{ kN/m}$   
Moist backfill above water table  $F_{m,a,f} = \gamma_{f,e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2 = 93.4 \text{ kN/m}$   
Total horizontal load  $F_{total,f} = F_{sur,f} + F_{m,a,f} = 111.4 \text{ kN/m}$

**Calculate total propping force**

Passive resistance of soil in front of wall  $F_{p,f} = \gamma_{f,e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb} = 0.3 \text{ kN/m}$   
Propping force  $F_{prop,f} = \max(F_{total,f} - F_{p,f} - (W_{total,f} - \gamma_{f,l} \times W_{live}) \times \tan(\delta_b), 0 \text{ kN/m})$   
 $F_{prop,f} = 78.7 \text{ kN/m}$

**Factored overturning moments**

Surcharge  $M_{sur,f} = F_{sur,f} \times (h_{eff} - 2 \times d_{ds}) / 2 = 29.7 \text{ kNm/m}$   
Moist backfill above water table  $M_{m,a,f} = F_{m,a,f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3 = 102.8 \text{ kNm/m}$   
Total overturning moment  $M_{ot,f} = M_{sur,f} + M_{m,a,f} = 132.5 \text{ kNm/m}$

**Restoring moments**

Wall stem  $M_{wall,f} = w_{wall,f} \times (l_{toe} + t_{wall} / 2) = 19 \text{ kNm/m}$   
Wall base  $M_{base,f} = w_{base,f} \times l_{base} / 2 = 2.9 \text{ kNm/m}$   
Design vertical load  $M_{v,f} = W_{v,f} \times l_{load} = 38.6 \text{ kNm/m}$   
Total restoring moment  $M_{rest,f} = M_{wall,f} + M_{base,f} + M_{v,f} = 60.5 \text{ kNm/m}$

**Factored bearing pressure**


Total vertical reaction  $R_f = W_{total,f} = 108.0 \text{ kN/m}$   
Distance to reaction  $x_{bar,f} = l_{base} / 2 = 383 \text{ mm}$   
Eccentricity of reaction  $e_f = \text{abs}((l_{base} / 2) - x_{bar,f}) = 0 \text{ mm}$

**Reaction acts within middle third of base**

Bearing pressure at toe  $p_{toe,f} = (R_f / l_{base}) - (6 \times R_f \times e_f / l_{base}^2) = 141.2 \text{ kN/m}^2$   
Bearing pressure at heel  $p_{heel,f} = (R_f / l_{base}) + (6 \times R_f \times e_f / l_{base}^2) = 141.2 \text{ kN/m}^2$   
Rate of change of base reaction  $\text{rate} = (p_{toe,f} - p_{heel,f}) / l_{base} = 0.00 \text{ kN/m}^2/\text{m}$   
Bearing pressure at stem / toe  $p_{stem\_toe,f} = \max(p_{toe,f} - (\text{rate} \times l_{toe}), 0 \text{ kN/m}^2) = 141.2 \text{ kN/m}^2$   
Bearing pressure at mid stem  $p_{stem\_mid,f} = \max(p_{toe,f} - (\text{rate} \times (l_{toe} + t_{wall} / 2)), 0 \text{ kN/m}^2) = 141.2 \text{ kN/m}^2$   
Bearing pressure at stem / heel  $p_{stem\_heel,f} = \max(p_{toe,f} - (\text{rate} \times (l_{toe} + t_{wall})), 0 \text{ kN/m}^2) = 141.2 \text{ kN/m}^2$

**Calculate propping forces to top and base of wall**

Propping force to top of wall  $F_{prop\_top,f} = (M_{ot,f} - M_{rest,f} + R_f \times l_{base} / 2 - F_{prop,f} \times t_{base} / 2) / (h_{stem} + t_{base} / 2) = 32.225 \text{ kN/m}$   
Propping force to base of wall  $F_{prop\_base,f} = F_{prop,f} - F_{prop\_top,f} = 46.487 \text{ kN/m}$

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

#### Material properties

Characteristic strength of concrete  $f_{cu} = 30 \text{ N/mm}^2$   
 Characteristic strength of reinforcement  $f_y = 500 \text{ N/mm}^2$

#### Base details

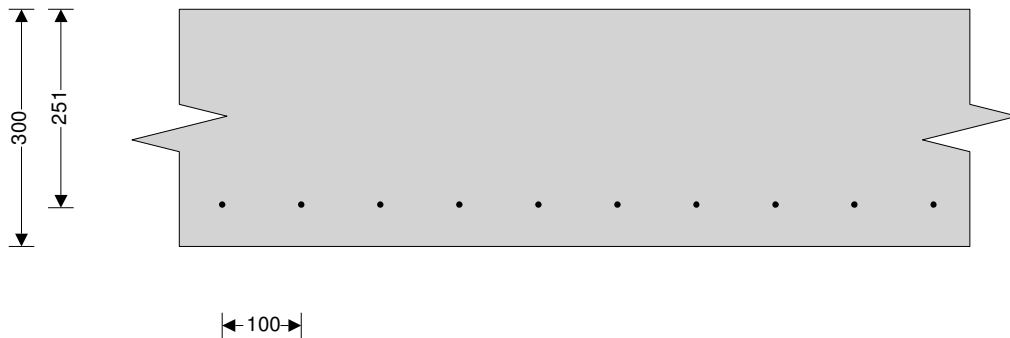
Minimum area of reinforcement  $k = 0.13 \%$   
 Cover to reinforcement in toe  $c_{toe} = 45 \text{ mm}$

#### Calculate shear for toe design

Shear from bearing pressure  $V_{toe\_bear} = (p_{toe\_f} + p_{stem\_toe\_f}) \times l_{toe} / 2 = 63.6 \text{ kN/m}$   
 Shear from weight of base  $V_{toe\_wt\_base} = \gamma_{fd} \times \gamma_{base} \times l_{toe} \times t_{base} = 4.5 \text{ kN/m}$   
 Total shear for toe design  $V_{toe} = V_{toe\_bear} - V_{toe\_wt\_base} = 59.1 \text{ kN/m}$

#### Calculate moment for toe design

Moment from bearing pressure  $M_{toe\_bear} = (2 \times p_{toe\_f} + p_{stem\_mid\_f}) \times (l_{toe} + t_{wall} / 2)^2 / 6 = 26.1 \text{ kNm/m}$   
 Moment from weight of base  $M_{toe\_wt\_base} = (\gamma_{fd} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2 / 2) = 1.8 \text{ kNm/m}$   
 Total moment for toe design  $M_{toe} = M_{toe\_bear} - M_{toe\_wt\_base} = 24.2 \text{ kNm/m}$



#### Check toe in bending

Width of toe  $b = 1000 \text{ mm/m}$   
 Depth of reinforcement  $d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2) = 251.0 \text{ mm}$   
 Constant  $K_{toe} = M_{toe} / (b \times d_{toe}^2 \times f_{cu}) = 0.013$

**Compression reinforcement is not required**

Lever arm  $Z_{toe} = \min(0.5 + \sqrt{(0.25 - (\min(K_{toe}, 0.225) / 0.9))}, 0.95) \times d_{toe}$   
 $Z_{toe} = 238 \text{ mm}$

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

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

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

Reinforcement provided

**C503 mesh**

Area of reinforcement provided

$A_{s\_toe\_prov} = 503 \text{ mm}^2/\text{m}$

**PASS - Reinforcement provided at the retaining wall toe is adequate**

#### Check shear resistance at toe

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


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

**PASS - Design shear stress is less than maximum shear stress**

#### From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress  $V_{c\_toe} = 0.441 \text{ N/mm}^2$

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

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

#### Material properties

Characteristic strength of concrete  $f_{cu} = 30 \text{ N/mm}^2$   
 Characteristic strength of reinforcement  $f_y = 500 \text{ N/mm}^2$

#### Wall details

Minimum area of reinforcement  $k = 0.13 \%$   
 Cover to reinforcement in stem  $C_{stem} = 45 \text{ mm}$   
 Cover to reinforcement in wall  $C_{wall} = 45 \text{ mm}$

#### Factored horizontal at-rest forces on stem

Surcharge  $F_{s\_sur\_f} = \gamma_{f_l} \times K_0 \times \text{Surcharge} \times (h_{eff} - t_{base} - d_{ds}) = 16.3 \text{ kN/m}$   
 Moist backfill above water table  $F_{s\_m\_a\_f} = 0.5 \times \gamma_{f_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2 = 77.2 \text{ kN/m}$

#### Calculate shear for stem design

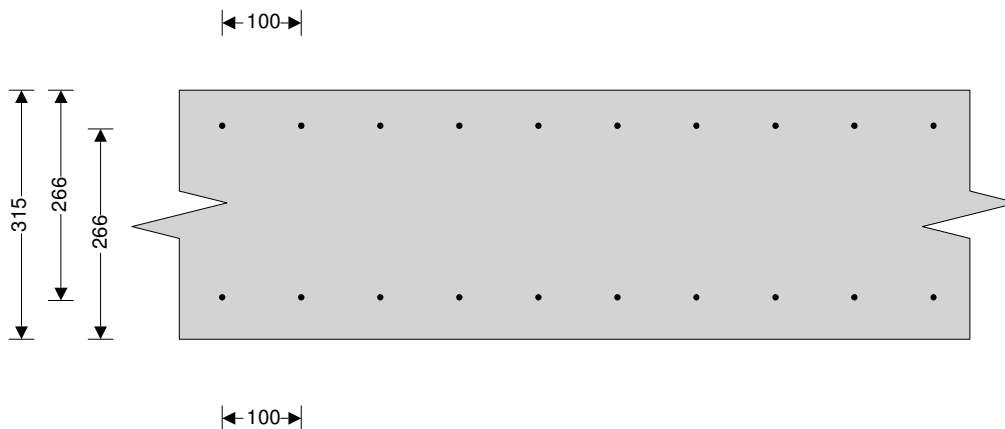
Surcharge  $V_{s\_sur\_f} = 5 \times F_{s\_sur\_f} / 8 = 10.2 \text{ kN/m}$   
 Moist backfill above water table  $V_{s\_m\_a\_f} = F_{s\_m\_a\_f} \times b_l \times ((5 \times L^2) - b^2) / (5 \times L^3) = 60.2 \text{ kN/m}$   
 Total shear for stem design  $V_{stem} = V_{s\_sur\_f} + V_{s\_m\_a\_f} = 70.4 \text{ kN/m}$

#### Calculate moment for stem design

Surcharge  $M_{s\_sur} = F_{s\_sur\_f} \times L / 8 = 6.4 \text{ kNm/m}$   
 Moist backfill above water table  $M_{s\_m\_a} = F_{s\_m\_a\_f} \times b_l \times ((5 \times L^2) - (3 \times b^2)) / (15 \times L^2) = 35.2 \text{ kNm/m}$   
 Total moment for stem design  $M_{stem} = M_{s\_sur} + M_{s\_m\_a} = 41.6 \text{ kNm/m}$

#### Calculate moment for wall design

Surcharge  $M_{w\_sur} = 9 \times F_{s\_sur\_f} \times L / 128 = 3.6 \text{ kNm/m}$   
 Moist backfill above water table  $M_{w\_m\_a} = F_{s\_m\_a\_f} \times 0.577 \times b_l \times [(b^3 + 5 \times a \times L^2) / (5 \times L^3) - 0.577^2 / 3] = 14.6 \text{ kNm/m}$   
 Total moment for wall design  $M_{wall} = M_{w\_sur} + M_{w\_m\_a} = 18.2 \text{ kNm/m}$



#### Check wall stem in bending

Width of wall stem  $b = 1000 \text{ mm/m}$   
 Depth of reinforcement  $d_{stem} = t_{wall} - C_{stem} - (\phi_{stem} / 2) = 266.0 \text{ mm}$   
 Constant  $K_{stem} = M_{stem} / (b \times d_{stem}^2 \times f_{cu}) = 0.020$

**Compression reinforcement is not required**

Lever arm  $Z_{stem} = \min(0.5 + \sqrt{(0.25 - (\min(K_{stem}, 0.225) / 0.9))}, 0.95) \times d_{stem}$   
 $Z_{stem} = 253 \text{ mm}$

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



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Minimum area of tension reinforcement

$$A_{s\_stem\_min} = k \times b \times t_{wall} = 410 \text{ mm}^2/\text{m}$$

Area of tension reinforcement required

$$A_{s\_stem\_req} = \text{Max}(A_{s\_stem\_des}, A_{s\_stem\_min}) = 410 \text{ mm}^2/\text{m}$$

Reinforcement provided

**C503 mesh**

Area of reinforcement provided

$$A_{s\_stem\_prov} = 503 \text{ mm}^2/\text{m}$$

**PASS - Reinforcement provided at the retaining wall stem is adequate**

**Check shear resistance at wall stem**

Design shear stress

$$v_{stem} = V_{stem} / (b \times d_{stem}) = 0.265 \text{ N/mm}^2$$

Allowable shear stress

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

**PASS - Design shear stress is less than maximum shear stress**

**From BS8110:Part 1:1997 – Table 3.8**

Design concrete shear stress

$$v_{c\_stem} = 0.427 \text{ N/mm}^2$$

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

**Check mid height of wall in bending**

Depth of reinforcement

$$d_{wall} = t_{wall} - c_{wall} - (\phi_{wall} / 2) = 266.0 \text{ mm}$$

Constant

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

**Compression reinforcement is not required**

Lever arm

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

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

Area of tension reinforcement required

$$A_{s\_wall\_des} = M_{wall} / (0.87 \times f_y \times z_{wall}) = 166 \text{ mm}^2/\text{m}$$

Minimum area of tension reinforcement

$$A_{s\_wall\_min} = k \times b \times t_{wall} = 410 \text{ mm}^2/\text{m}$$

Area of tension reinforcement required

$$A_{s\_wall\_req} = \text{Max}(A_{s\_wall\_des}, A_{s\_wall\_min}) = 410 \text{ mm}^2/\text{m}$$

Reinforcement provided

**C503 mesh**

Area of reinforcement provided

$$A_{s\_wall\_prov} = 503 \text{ mm}^2/\text{m}$$

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

**Check retaining wall deflection**

Basic span/effective depth ratio

$$\text{ratio}_{bas} = 20$$

Design service stress

$$f_s = 2 \times f_y \times A_{s\_stem\_req} / (3 \times A_{s\_stem\_prov}) = 271.6 \text{ N/mm}^2$$

Modification factor

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

Maximum span/effective depth ratio

$$\text{ratio}_{max} = \text{ratio}_{bas} \times \text{factor}_{tens} = 34.00$$

Actual span/effective depth ratio

$$\text{ratio}_{act} = h_{stem} / d_{stem} = 11.28$$

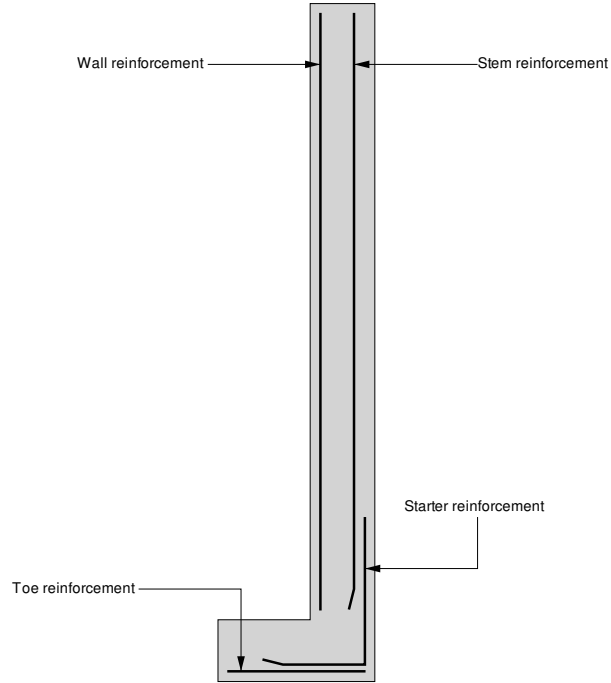
**PASS - Span to depth ratio is acceptable**



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**Indicative retaining wall reinforcement diagram**



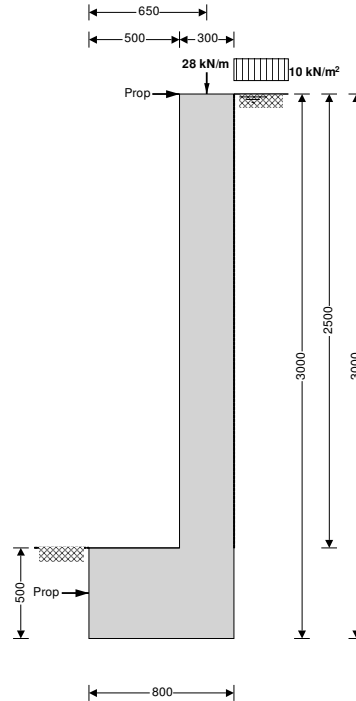
Toe mesh - C503 - (503 mm<sup>2</sup>/m)  
Wall mesh - C503 - (503 mm<sup>2</sup>/m)  
Stem mesh - C503 - (503 mm<sup>2</sup>/m)



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**RETAINING WALL ANALYSIS (BS 8002:1994)**

TEDDS calculation version 1.2.01.06



**Wall details**

- Retaining wall type
- Height of retaining wall stem
- Thickness of wall stem
- Length of toe
- Length of heel
- Overall length of base
- Thickness of base
- Depth of downstand
- Position of downstand
- Thickness of downstand
- Height of retaining wall
- Depth of cover in front of wall
- Depth of unplanned excavation
- Height of ground water behind wall
- Height of saturated fill above base
- Density of wall construction
- Density of base construction
- Angle of rear face of wall
- Angle of soil surface behind wall
- Effective height at virtual back of wall

**Cantilever propped at both**

- $h_{stem} = 2500$  mm
- $t_{wall} = 300$  mm
- $l_{toe} = 500$  mm
- $l_{heel} = 0$  mm
- $l_{base} = l_{toe} + l_{heel} + t_{wall} = 800$  mm
- $t_{base} = 500$  mm
- $d_{ds} = 0$  mm
- $l_{ds} = 15$  mm
- $t_{ds} = 500$  mm
- $h_{wall} = h_{stem} + t_{base} + d_{ds} = 3000$  mm
- $d_{cover} = 0$  mm
- $d_{exc} = 0$  mm
- $h_{water} = 3000$  mm
- $h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0 \text{ mm}) = 2500$  mm
- $\gamma_{wall} = 23.6$  kN/m<sup>3</sup>
- $\gamma_{base} = 23.6$  kN/m<sup>3</sup>
- $\alpha = 90.0$  deg
- $\beta = 0.0$  deg
- $h_{eff} = h_{wall} + l_{heel} \times \tan(\beta) = 3000$  mm

**Retained material details**

- Mobilisation factor  
 $M = 1.5$
- Moist density of retained material  
 $\gamma_m = 18.0$  kN/m<sup>3</sup>

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Saturated density of retained material  $\gamma_s = 21.0 \text{ kN/m}^3$   
 Design shear strength  $\phi' = 18.6 \text{ deg}$   
 Angle of wall friction  $\delta = 0.0 \text{ deg}$

**Base material details**

Firm clay  
 Moist density  $\gamma_{mb} = 18.0 \text{ kN/m}^3$   
 Design shear strength  $\phi'_b = 16.5 \text{ deg}$   
 Design base friction  $\delta_b = 18.6 \text{ deg}$   
 Allowable bearing pressure  $P_{\text{bearing}} = 100 \text{ kN/m}^2$

**Using Coulomb theory**

Active pressure coefficient for retained material

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

Passive pressure coefficient for base material

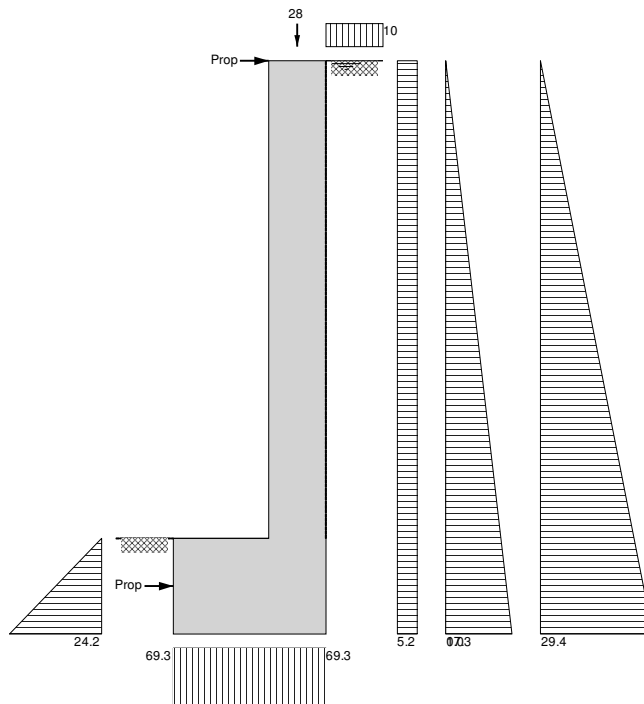
$$K_p = \sin(90 - \phi'_b)^2 / (\sin(90 - \delta_b) \times [1 - \sqrt{(\sin(\phi'_b + \delta_b) \times \sin(\phi'_b) / (\sin(90 + \delta_b)))^2}] = 2.835$$

**At-rest pressure**

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

**Loading details**

Surcharge load on plan Surcharge = 10.0 kN/m<sup>2</sup>  
 Applied vertical dead load on wall  $W_{\text{dead}} = 20.3 \text{ kN/m}$   
 Applied vertical live load on wall  $W_{\text{live}} = 8.0 \text{ kN/m}$   
 Position of applied vertical load on wall  $l_{\text{load}} = 650 \text{ mm}$   
 Applied horizontal dead load on wall  $F_{\text{dead}} = 0.0 \text{ kN/m}$   
 Applied horizontal live load on wall  $F_{\text{live}} = 0.0 \text{ kN/m}$   
 Height of applied horizontal load on wall  $h_{\text{load}} = 0 \text{ mm}$



Loads shown in kN/m, pressures shown in kN/m<sup>2</sup>

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### Vertical forces on wall

Wall stem	$W_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall} = 17.7 \text{ kN/m}$
Wall base	$W_{base} = l_{base} \times t_{base} \times \gamma_{base} = 9.4 \text{ kN/m}$
Applied vertical load	$W_v = W_{dead} + W_{live} = 28.3 \text{ kN/m}$
Total vertical load	$W_{total} = W_{wall} + W_{base} + W_v = 55.5 \text{ kN/m}$

### Horizontal forces on wall

Surcharge	$F_{sur} = K_a \times \text{Surcharge} \times h_{eff} = 15.5 \text{ kN/m}$
Saturated backfill	$F_s = 0.5 \times K_a \times (\gamma_s - \gamma_{water}) \times h_{water}^2 = 26 \text{ kN/m}$
Water	$F_{water} = 0.5 \times h_{water}^2 \times \gamma_{water} = 44.1 \text{ kN/m}$
Total horizontal load	$F_{total} = F_{sur} + F_s + F_{water} = 85.6 \text{ kN/m}$

### Calculate total propping force

Passive resistance of soil in front of wall	$F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb} = 6 \text{ kN/m}$
Propping force	$F_{prop} = \max(F_{total} - F_p - (W_{total} - W_{live}) \times \tan(\delta_b), 0 \text{ kN/m})$ $F_{prop} = 63.6 \text{ kN/m}$

### Overturning moments

Surcharge	$M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2 = 23.2 \text{ kNm/m}$
Saturated backfill	$M_s = F_s \times (h_{water} - 3 \times d_{ds}) / 3 = 26 \text{ kNm/m}$
Water	$M_{water} = F_{water} \times (h_{water} - 3 \times d_{ds}) / 3 = 44.1 \text{ kNm/m}$
Total overturning moment	$M_{ot} = M_{sur} + M_s + M_{water} = 93.4 \text{ kNm/m}$

### Restoring moments

Wall stem	$M_{wall} = W_{wall} \times (l_{toe} + t_{wall} / 2) = 11.5 \text{ kNm/m}$
Wall base	$M_{base} = W_{base} \times l_{base} / 2 = 3.8 \text{ kNm/m}$
Design vertical dead load	$M_{dead} = W_{dead} \times l_{load} = 13.2 \text{ kNm/m}$
Total restoring moment	$M_{rest} = M_{wall} + M_{base} + M_{dead} = 28.5 \text{ kNm/m}$

### Check bearing pressure

Total vertical reaction	$R = W_{total} = 55.5 \text{ kN/m}$
Distance to reaction	$X_{bar} = l_{base} / 2 = 400 \text{ mm}$
Eccentricity of reaction	$e = \text{abs}((l_{base} / 2) - X_{bar}) = 0 \text{ mm}$

**Reaction acts within middle third of base**

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

**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	$F_{prop\_top} = (M_{ot} - M_{rest} + R \times l_{base} / 2 - F_{prop} \times t_{base} / 2) / (h_{stem} + t_{base} / 2) = 25.881 \text{ kN/m}$
Propping force to base of wall	$F_{prop\_base} = F_{prop} - F_{prop\_top} = 37.737 \text{ kN/m}$



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**RETAINING WALL DESIGN (BS 8002:1994)**

TEDDS calculation version 1.2.01.06

**Ultimate limit state load factors**

Dead load factor  $\gamma_{f,d} = 1.4$   
Live load factor  $\gamma_{f,l} = 1.6$   
Earth and water pressure factor  $\gamma_{f,e} = 1.4$

**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  $F_{sur,f} = \gamma_{f,l} \times K_0 \times \text{Surcharge} \times h_{eff} = 32.7$  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  $F_{prop,f} = \max(F_{total,f} - F_{p,f} - (W_{total,f} - \gamma_{f,l} \times W_{live}) \times \tan(\delta_b), 0$  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/m<sup>2</sup>  
Bearing pressure at heel  $p_{heel,f} = (R_f / l_{base}) + (6 \times R_f \times e_f / l_{base}^2) = 99.1$  kN/m<sup>2</sup>  
Rate of change of base reaction  $\text{rate} = (p_{toe,f} - p_{heel,f}) / l_{base} = 0.00$  kN/m<sup>2</sup>/m  
Bearing pressure at stem / toe  $p_{stem\_toe,f} = \max(p_{toe,f} - (\text{rate} \times l_{toe}), 0$  kN/m<sup>2</sup>) = 99.1 kN/m<sup>2</sup>  
Bearing pressure at mid stem  $p_{stem\_mid,f} = \max(p_{toe,f} - (\text{rate} \times (l_{toe} + t_{wall} / 2)), 0$  kN/m<sup>2</sup>) = 99.1 kN/m<sup>2</sup>  
Bearing pressure at stem / heel  $p_{stem\_heel,f} = \max(p_{toe,f} - (\text{rate} \times (l_{toe} + t_{wall})), 0$  kN/m<sup>2</sup>) = 99.1 kN/m<sup>2</sup>

**Calculate propping forces to top and base of wall**

Propping force to top of wall

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

Propping force to base of wall

$$F_{prop\_base\_f} = F_{prop\_f} - F_{prop\_top\_f} = 70.070 \text{ kN/m}$$

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

**Material properties**

Characteristic strength of concrete

$$f_{cu} = 40 \text{ N/mm}^2$$

Characteristic strength of reinforcement

$$f_y = 500 \text{ N/mm}^2$$

**Base details**

Minimum area of reinforcement

$$k = 0.13 \%$$

Cover to reinforcement in toe

$$c_{toe} = 45 \text{ mm}$$

**Calculate shear for toe design**

Shear from bearing pressure

$$V_{toe\_bear} = (p_{toe\_f} + p_{stem\_toe\_f}) \times l_{toe} / 2 = 49.5 \text{ kN/m}$$

Shear from weight of base

$$V_{toe\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{toe} \times t_{base} = 8.3 \text{ kN/m}$$

Total shear for toe design

$$V_{toe} = V_{toe\_bear} - V_{toe\_wt\_base} = 41.3 \text{ kN/m}$$

**Calculate moment for toe design**

Moment from bearing pressure

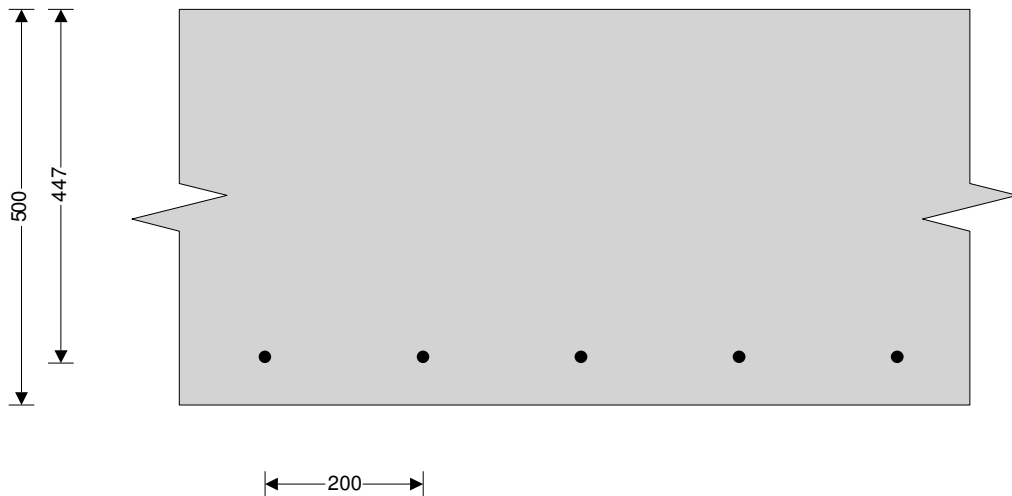
$$M_{toe\_bear} = (2 \times p_{toe\_f} + p_{stem\_mid\_f}) \times (l_{toe} + t_{wall} / 2)^2 / 6 = 20.9 \text{ kNm/m}$$

Moment from weight of base

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

Total moment for toe design

$$M_{toe} = M_{toe\_bear} - M_{toe\_wt\_base} = 17.4 \text{ kNm/m}$$



**Check toe in bending**

Width of toe

$$b = 1000 \text{ mm/m}$$

Depth of reinforcement

$$d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2) = 447.0 \text{ mm}$$

Constant

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

**Compression reinforcement is not required**

Lever arm

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

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

Area of tension reinforcement required

$$A_{s\_toe\_des} = M_{toe} / (0.87 \times f_y \times z_{toe}) = 94 \text{ mm}^2/\text{m}$$

Minimum area of tension reinforcement

$$A_{s\_toe\_min} = k \times b \times t_{base} = 650 \text{ mm}^2/\text{m}$$

Area of tension reinforcement required

$$A_{s\_toe\_req} = \text{Max}(A_{s\_toe\_des}, A_{s\_toe\_min}) = 650 \text{ mm}^2/\text{m}$$

Reinforcement provided

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

Area of reinforcement provided

$$A_{s\_toe\_prov} = 1005 \text{ mm}^2/\text{m}$$

**PASS - Reinforcement provided at the retaining wall toe is adequate**

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### Check shear resistance at toe

Design shear stress

$$v_{toe} = V_{toe} / (b \times d_{toe}) = 0.092 \text{ N/mm}^2$$

Allowable shear stress

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

**PASS - Design shear stress is less than maximum shear stress**

### From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress

$$v_{c\_toe} = 0.450 \text{ N/mm}^2$$

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

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

#### Material properties

Characteristic strength of concrete

$$f_{cu} = 40 \text{ N/mm}^2$$

Characteristic strength of reinforcement

$$f_y = 500 \text{ N/mm}^2$$

#### Wall details

Minimum area of reinforcement

$$k = 0.13 \%$$

Cover to reinforcement in stem

$$c_{stem} = 45 \text{ mm}$$

Cover to reinforcement in wall

$$c_{wall} = 45 \text{ mm}$$

#### Factored horizontal at-rest forces on stem

Surcharge

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

Saturated backfill

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

Water

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

#### Calculate shear for stem design

Surcharge

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

Saturated backfill

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

Water

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

Total shear for stem design

$$V_{stem} = V_{s\_sur\_f} + V_{s\_s\_f} + V_{s\_water\_f} = 78 \text{ kN/m}$$

#### Calculate moment for stem design

Surcharge

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

Saturated backfill

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

Water

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

kNm/m

Total moment for stem design

$$M_{stem} = M_{s\_sur} + M_{s\_s} + M_{s\_water} = 37.3 \text{ kNm/m}$$

#### Calculate moment for wall design

Surcharge

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

Saturated backfill

$$M_{w\_s} = F_{s\_s\_f} \times [a^2 \times ((5 \times L) - a) / (20 \times L^3) - (x - b)^3 / (3 \times a^2)] = 5.5 \text{ kNm/m}$$

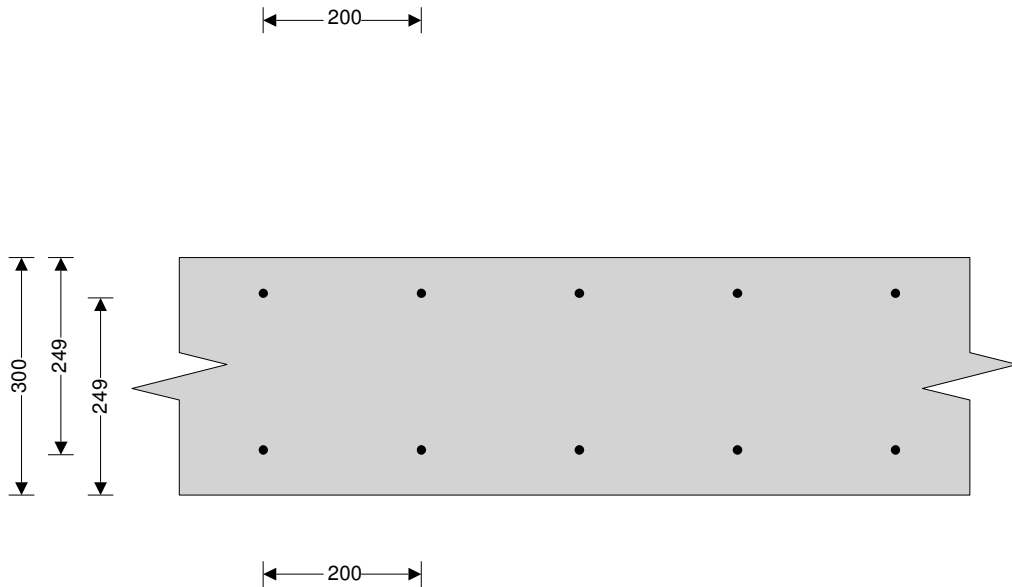
Water

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

Total moment for wall design

$$M_{wall} = M_{w\_sur} + M_{w\_s} + M_{w\_water} = 17.8 \text{ kNm/m}$$

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### Check wall stem in bending

Width of wall stem

$$b = 1000 \text{ mm/m}$$

Depth of reinforcement

$$d_{\text{stem}} = t_{\text{wall}} - c_{\text{stem}} - (\phi_{\text{stem}} / 2) = 249.0 \text{ mm}$$

Constant

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

**Compression reinforcement is not required**

Lever arm

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

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

Area of tension reinforcement required

$$A_{\text{s\_stem\_des}} = M_{\text{stem}} / (0.87 \times f_y \times z_{\text{stem}}) = 363 \text{ mm}^2/\text{m}$$

Minimum area of tension reinforcement

$$A_{\text{s\_stem\_min}} = k \times b \times t_{\text{wall}} = 390 \text{ mm}^2/\text{m}$$

Area of tension reinforcement required

$$A_{\text{s\_stem\_req}} = \text{Max}(A_{\text{s\_stem\_des}}, A_{\text{s\_stem\_min}}) = 390 \text{ mm}^2/\text{m}$$

Reinforcement provided

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

Area of reinforcement provided

$$A_{\text{s\_stem\_prov}} = 565 \text{ mm}^2/\text{m}$$

**PASS - Reinforcement provided at the retaining wall stem is adequate**

### Check shear resistance at wall stem

Design shear stress

$$v_{\text{stem}} = V_{\text{stem}} / (b \times d_{\text{stem}}) = 0.313 \text{ N/mm}^2$$

Allowable shear stress

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

**PASS - Design shear stress is less than maximum shear stress**

### From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress

$$v_{\text{c\_stem}} = 0.508 \text{ N/mm}^2$$

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

### Check mid height of wall in bending

Depth of reinforcement

$$d_{\text{wall}} = t_{\text{wall}} - c_{\text{wall}} - (\phi_{\text{wall}} / 2) = 249.0 \text{ mm}$$

Constant

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

**Compression reinforcement is not required**

Lever arm

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

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

Area of tension reinforcement required

$$A_{\text{s\_wall\_des}} = M_{\text{wall}} / (0.87 \times f_y \times z_{\text{wall}}) = 173 \text{ mm}^2/\text{m}$$

Minimum area of tension reinforcement

$$A_{\text{s\_wall\_min}} = k \times b \times t_{\text{wall}} = 390 \text{ mm}^2/\text{m}$$

Area of tension reinforcement required

$$A_{\text{s\_wall\_req}} = \text{Max}(A_{\text{s\_wall\_des}}, A_{\text{s\_wall\_min}}) = 390 \text{ mm}^2/\text{m}$$



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Reinforcement provided

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

Area of reinforcement provided

$A_{s\_wall\_prov} = 565 \text{ mm}^2/\text{m}$

**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

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

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

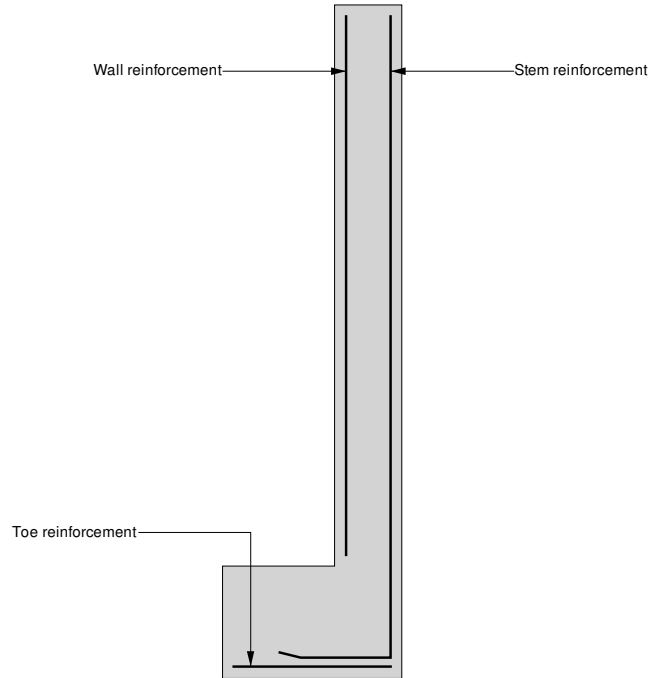
$ratio_{act} = h_{stem} / d_{stem} = 10.04$

**PASS - Span to depth ratio is acceptable**



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**Indicative retaining wall reinforcement diagram**

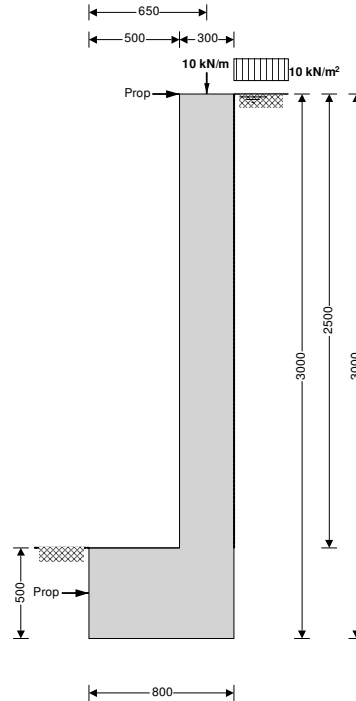


- Toe bars - 16 mm dia.@ 200 mm centres - (1005 mm<sup>2</sup>/m)
- Wall bars - 12 mm dia.@ 200 mm centres - (565 mm<sup>2</sup>/m)
- Stem bars - 12 mm dia.@ 200 mm centres - (565 mm<sup>2</sup>/m)

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**RETAINING WALL ANALYSIS (BS 8002:1994)**

TEDDS calculation version 1.2.01.06



**Wall details**

- Retaining wall type
- Height of retaining wall stem
- Thickness of wall stem
- Length of toe
- Length of heel
- Overall length of base
- Thickness of base
- Depth of downstand
- Position of downstand
- Thickness of downstand
- Height of retaining wall
- Depth of cover in front of wall
- Depth of unplanned excavation
- Height of ground water behind wall
- Height of saturated fill above base
- Density of wall construction
- Density of base construction
- Angle of rear face of wall
- Angle of soil surface behind wall
- Effective height at virtual back of wall

**Cantilever propped at both**

- $h_{stem} = 2500$  mm
- $t_{wall} = 300$  mm
- $l_{toe} = 500$  mm
- $l_{heel} = 0$  mm
- $l_{base} = l_{toe} + l_{heel} + t_{wall} = 800$  mm
- $t_{base} = 500$  mm
- $d_{ds} = 0$  mm
- $l_{ds} = 300$  mm
- $t_{ds} = 500$  mm
- $h_{wall} = h_{stem} + t_{base} + d_{ds} = 3000$  mm
- $d_{cover} = 0$  mm
- $d_{exc} = 0$  mm
- $h_{water} = 3000$  mm
- $h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0 \text{ mm}) = 2500$  mm
- $\gamma_{wall} = 23.6$  kN/m<sup>3</sup>
- $\gamma_{base} = 23.6$  kN/m<sup>3</sup>
- $\alpha = 90.0$  deg
- $\beta = 0.0$  deg
- $h_{eff} = h_{wall} + l_{heel} \times \tan(\beta) = 3000$  mm

**Retained material details**

- Mobilisation factor **M = 1.5**
- Moist density of retained material  **$\gamma_m = 18.0$  kN/m<sup>3</sup>**

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Saturated density of retained material  $\gamma_s = 21.0 \text{ kN/m}^3$   
 Design shear strength  $\phi' = 18.6 \text{ deg}$   
 Angle of wall friction  $\delta = 0.0 \text{ deg}$

**Base material details**

Firm clay  
 Moist density  $\gamma_{mb} = 18.0 \text{ kN/m}^3$   
 Design shear strength  $\phi'_b = 16.5 \text{ deg}$   
 Design base friction  $\delta_b = 18.6 \text{ deg}$   
 Allowable bearing pressure  $P_{\text{bearing}} = 100 \text{ kN/m}^2$

**Using Coulomb theory**

Active pressure coefficient for retained material

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

Passive pressure coefficient for base material

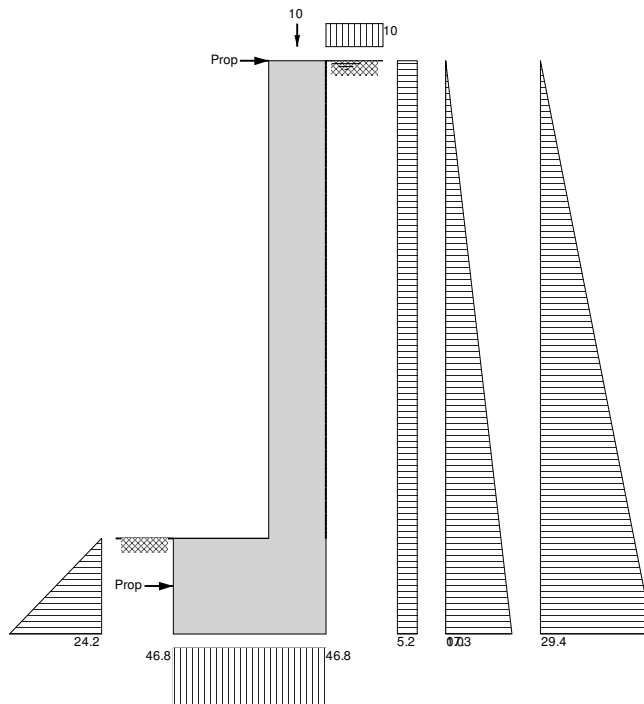
$$K_p = \sin(90 - \phi'_b)^2 / (\sin(90 - \delta_b) \times [1 - \sqrt{(\sin(\phi'_b + \delta_b) \times \sin(\phi'_b) / (\sin(90 + \delta_b)))]^2) = 2.835$$

**At-rest pressure**

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

**Loading details**

Surcharge load on plan **Surcharge = 10.0 kN/m<sup>2</sup>**  
 Applied vertical dead load on wall  **$W_{\text{dead}} = 10.3 \text{ kN/m}$**   
 Applied vertical live load on wall  **$W_{\text{live}} = 0.0 \text{ kN/m}$**   
 Position of applied vertical load on wall  **$l_{\text{load}} = 650 \text{ mm}$**   
 Applied horizontal dead load on wall  **$F_{\text{dead}} = 0.0 \text{ kN/m}$**   
 Applied horizontal live load on wall  **$F_{\text{live}} = 0.0 \text{ kN/m}$**   
 Height of applied horizontal load on wall  **$h_{\text{load}} = 0 \text{ mm}$**



Loads shown in kN/m, pressures shown in kN/m<sup>2</sup>

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### Vertical forces on wall

Wall stem	$W_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall} = 17.7 \text{ kN/m}$
Wall base	$W_{base} = l_{base} \times t_{base} \times \gamma_{base} = 9.4 \text{ kN/m}$
Applied vertical load	$W_v = W_{dead} + W_{live} = 10.3 \text{ kN/m}$
Total vertical load	$W_{total} = W_{wall} + W_{base} + W_v = 37.4 \text{ kN/m}$

### Horizontal forces on wall

Surcharge	$F_{sur} = K_a \times \text{Surcharge} \times h_{eff} = 15.5 \text{ kN/m}$
Saturated backfill	$F_s = 0.5 \times K_a \times (\gamma_s - \gamma_{water}) \times h_{water}^2 = 26 \text{ kN/m}$
Water	$F_{water} = 0.5 \times h_{water}^2 \times \gamma_{water} = 44.1 \text{ kN/m}$
Total horizontal load	$F_{total} = F_{sur} + F_s + F_{water} = 85.6 \text{ kN/m}$

### Calculate total propping force

Passive resistance of soil in front of wall	$F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb} = 6 \text{ kN/m}$
Propping force	$F_{prop} = \max(F_{total} - F_p - (W_{total}) \times \tan(\delta_b), 0 \text{ kN/m})$ $F_{prop} = 67.0 \text{ kN/m}$

### Overturning moments

Surcharge	$M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2 = 23.2 \text{ kNm/m}$
Saturated backfill	$M_s = F_s \times (h_{water} - 3 \times d_{ds}) / 3 = 26 \text{ kNm/m}$
Water	$M_{water} = F_{water} \times (h_{water} - 3 \times d_{ds}) / 3 = 44.1 \text{ kNm/m}$
Total overturning moment	$M_{ot} = M_{sur} + M_s + M_{water} = 93.4 \text{ kNm/m}$

### Restoring moments

Wall stem	$M_{wall} = W_{wall} \times (l_{toe} + t_{wall} / 2) = 11.5 \text{ kNm/m}$
Wall base	$M_{base} = W_{base} \times l_{base} / 2 = 3.8 \text{ kNm/m}$
Design vertical dead load	$M_{dead} = W_{dead} \times l_{load} = 6.7 \text{ kNm/m}$
Total restoring moment	$M_{rest} = M_{wall} + M_{base} + M_{dead} = 22 \text{ kNm/m}$

### Check bearing pressure

Total vertical reaction	$R = W_{total} = 37.4 \text{ kN/m}$
Distance to reaction	$X_{bar} = l_{base} / 2 = 400 \text{ mm}$
Eccentricity of reaction	$e = \text{abs}((l_{base} / 2) - X_{bar}) = 0 \text{ mm}$

**Reaction acts within middle third of base**

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

**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	$F_{prop\_top} = (M_{ot} - M_{rest} + R \times l_{base} / 2 - F_{prop} \times t_{base} / 2) / (h_{stem} + t_{base} / 2) = 25.324 \text{ kN/m}$
Propping force to base of wall	$F_{prop\_base} = F_{prop} - F_{prop\_top} = 41.679 \text{ kN/m}$



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**RETAINING WALL DESIGN (BS 8002:1994)**

TEDDS calculation version 1.2.01.06

**Ultimate limit state load factors**

Dead load factor  $\gamma_{f,d} = 1.4$   
 Live load factor  $\gamma_{f,l} = 1.6$   
 Earth and water pressure factor  $\gamma_{f,e} = 1.4$

**Factored vertical forces on wall**

Wall stem  $W_{wall,f} = \gamma_{f,d} \times h_{stem} \times t_{wall} \times \gamma_{wall} = 24.8 \text{ kN/m}$   
 Wall base  $W_{base,f} = \gamma_{f,d} \times l_{base} \times t_{base} \times \gamma_{base} = 13.2 \text{ kN/m}$   
 Applied vertical load  $W_{v,f} = \gamma_{f,d} \times W_{dead} + \gamma_{f,l} \times W_{live} = 14.4 \text{ kN/m}$   
 Total vertical load  $W_{total,f} = W_{wall,f} + W_{base,f} + W_{v,f} = 52.4 \text{ kN/m}$

**Factored horizontal at-rest forces on wall**

Surcharge  $F_{sur,f} = \gamma_{f,l} \times K_0 \times \text{Surcharge} \times h_{eff} = 32.7 \text{ kN/m}$   
 Saturated backfill  $F_{s,f} = \gamma_{f,e} \times 0.5 \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{water}^2 = 48 \text{ kN/m}$   
 Water  $F_{water,f} = \gamma_{f,e} \times 0.5 \times h_{water}^2 \times \gamma_{water} = 61.8 \text{ kN/m}$   
 Total horizontal load  $F_{total,f} = F_{sur,f} + F_{s,f} + F_{water,f} = 142.5 \text{ kN/m}$

**Calculate total propping force**

Passive resistance of soil in front of wall  $F_{p,f} = \gamma_{f,e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb} = 8.5 \text{ kN/m}$   
 Propping force  $F_{prop,f} = \max(F_{total,f} - F_{p,f} - (W_{total,f}) \times \tan(\delta_b), 0 \text{ kN/m})$   
 $F_{prop,f} = 116.4 \text{ kN/m}$

**Factored overturning moments**

Surcharge  $M_{sur,f} = F_{sur,f} \times (h_{eff} - 2 \times d_{ds}) / 2 = 49 \text{ kNm/m}$   
 Saturated backfill  $M_{s,f} = F_{s,f} \times (h_{water} - 3 \times d_{ds}) / 3 = 48 \text{ kNm/m}$   
 Water  $M_{water,f} = F_{water,f} \times (h_{water} - 3 \times d_{ds}) / 3 = 61.8 \text{ kNm/m}$   
 Total overturning moment  $M_{ot,f} = M_{sur,f} + M_{s,f} + M_{water,f} = 158.8 \text{ kNm/m}$

**Restoring moments**

Wall stem  $M_{wall,f} = W_{wall,f} \times (l_{toe} + t_{wall} / 2) = 16.1 \text{ kNm/m}$   
 Wall base  $M_{base,f} = W_{base,f} \times l_{base} / 2 = 5.3 \text{ kNm/m}$   
 Design vertical load  $M_{v,f} = W_{v,f} \times l_{load} = 9.3 \text{ kNm/m}$   
 Total restoring moment  $M_{rest,f} = M_{wall,f} + M_{base,f} + M_{v,f} = 30.7 \text{ kNm/m}$

**Factored bearing pressure**


Total vertical reaction  $R_f = W_{total,f} = 52.4 \text{ kN/m}$   
 Distance to reaction  $x_{bar,f} = l_{base} / 2 = 400 \text{ mm}$   
 Eccentricity of reaction  $e_f = \text{abs}((l_{base} / 2) - x_{bar,f}) = 0 \text{ mm}$

**Reaction acts within middle third of base**

Bearing pressure at toe  $p_{toe,f} = (R_f / l_{base}) - (6 \times R_f \times e_f / l_{base}^2) = 65.5 \text{ kN/m}^2$   
 Bearing pressure at heel  $p_{heel,f} = (R_f / l_{base}) + (6 \times R_f \times e_f / l_{base}^2) = 65.5 \text{ kN/m}^2$   
 Rate of change of base reaction  $\text{rate} = (p_{toe,f} - p_{heel,f}) / l_{base} = 0.00 \text{ kN/m}^2/\text{m}$   
 Bearing pressure at stem / toe  $p_{stem\_toe,f} = \max(p_{toe,f} - (\text{rate} \times l_{toe}), 0 \text{ kN/m}^2) = 65.5 \text{ kN/m}^2$   
 Bearing pressure at mid stem  $p_{stem\_mid,f} = \max(p_{toe,f} - (\text{rate} \times (l_{toe} + t_{wall} / 2)), 0 \text{ kN/m}^2) = 65.5 \text{ kN/m}^2$   
 Bearing pressure at stem / heel  $p_{stem\_heel,f} = \max(p_{toe,f} - (\text{rate} \times (l_{toe} + t_{wall})), 0 \text{ kN/m}^2) = 65.5 \text{ kN/m}^2$

**Calculate propping forces to top and base of wall**

Propping force to top of wall

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

Propping force to base of wall

$$F_{prop\_base\_f} = F_{prop\_f} - F_{prop\_top\_f} = 72.797 \text{ kN/m}$$

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

#### Material properties

Characteristic strength of concrete

$$f_{cu} = 40 \text{ N/mm}^2$$

Characteristic strength of reinforcement

$$f_y = 500 \text{ N/mm}^2$$

#### Base details

Minimum area of reinforcement

$$k = 0.13 \%$$

Cover to reinforcement in toe

$$c_{toe} = 45 \text{ mm}$$

#### Calculate shear for toe design

Shear from bearing pressure

$$V_{toe\_bear} = (p_{toe\_f} + p_{stem\_toe\_f}) \times l_{toe} / 2 = 32.7 \text{ kN/m}$$

Shear from weight of base

$$V_{toe\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{toe} \times t_{base} = 8.3 \text{ kN/m}$$

Total shear for toe design

$$V_{toe} = V_{toe\_bear} - V_{toe\_wt\_base} = 24.5 \text{ kN/m}$$

#### Calculate moment for toe design

Moment from bearing pressure

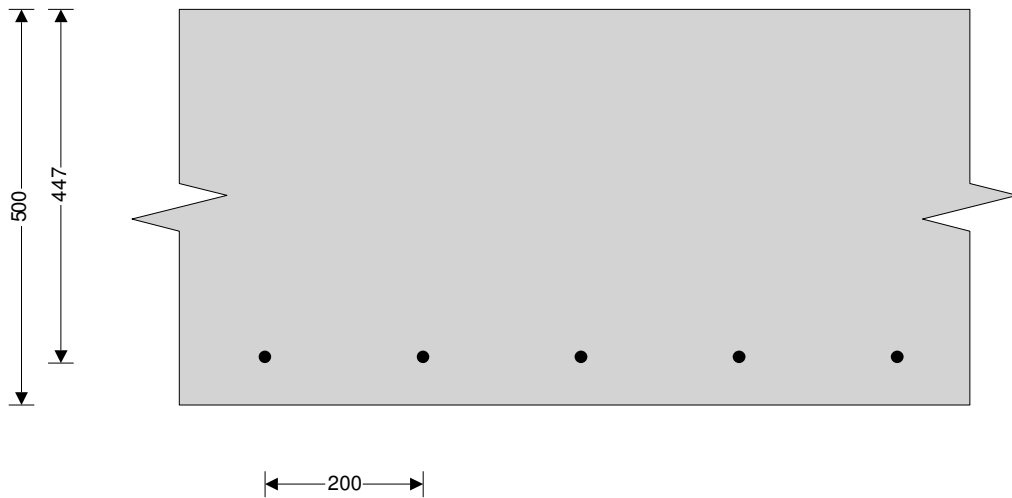
$$M_{toe\_bear} = (2 \times p_{toe\_f} + p_{stem\_mid\_f}) \times (l_{toe} + t_{wall} / 2)^2 / 6 = 13.8 \text{ kNm/m}$$

Moment from weight of base

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

Total moment for toe design

$$M_{toe} = M_{toe\_bear} - M_{toe\_wt\_base} = 10.3 \text{ kNm/m}$$



#### Check toe in bending

Width of toe

$$b = 1000 \text{ mm/m}$$

Depth of reinforcement

$$d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2) = 447.0 \text{ mm}$$

Constant

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

**Compression reinforcement is not required**

Lever arm

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

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

Area of tension reinforcement required

$$A_{s\_toe\_des} = M_{toe} / (0.87 \times f_y \times z_{toe}) = 56 \text{ mm}^2/\text{m}$$

Minimum area of tension reinforcement

$$A_{s\_toe\_min} = k \times b \times t_{base} = 650 \text{ mm}^2/\text{m}$$

Area of tension reinforcement required

$$A_{s\_toe\_req} = \text{Max}(A_{s\_toe\_des}, A_{s\_toe\_min}) = 650 \text{ mm}^2/\text{m}$$


Reinforcement provided

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

Area of reinforcement provided

$$A_{s\_toe\_prov} = 1005 \text{ mm}^2/\text{m}$$

**PASS - Reinforcement provided at the retaining wall toe is adequate**

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### Check shear resistance at toe

Design shear stress

$$V_{toe} = V_{toe} / (b \times d_{toe}) = \mathbf{0.055 \text{ N/mm}^2}$$

Allowable shear stress

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

**PASS - Design shear stress is less than maximum shear stress**

### From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress

$$V_{c\_toe} = \mathbf{0.450 \text{ N/mm}^2}$$

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

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

#### Material properties

Characteristic strength of concrete

$$f_{cu} = \mathbf{40 \text{ N/mm}^2}$$

Characteristic strength of reinforcement

$$f_y = \mathbf{500 \text{ N/mm}^2}$$

#### Wall details

Minimum area of reinforcement

$$k = \mathbf{0.13 \%}$$

Cover to reinforcement in stem

$$C_{stem} = \mathbf{45 \text{ mm}}$$

Cover to reinforcement in wall

$$C_{wall} = \mathbf{45 \text{ mm}}$$

#### Factored horizontal at-rest forces on stem

Surcharge

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

Saturated backfill

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

Water

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

#### Calculate shear for stem design

Surcharge

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

Saturated backfill

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

Water

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

Total shear for stem design

$$V_{stem} = V_{s\_sur\_f} + V_{s\_s\_f} + V_{s\_water\_f} = \mathbf{78 \text{ kN/m}}$$

#### Calculate moment for stem design

Surcharge

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

Saturated backfill

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

Water

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

kNm/m

Total moment for stem design

$$M_{stem} = M_{s\_sur} + M_{s\_s} + M_{s\_water} = \mathbf{37.3 \text{ kNm/m}}$$

#### Calculate moment for wall design

Surcharge

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

Saturated backfill


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

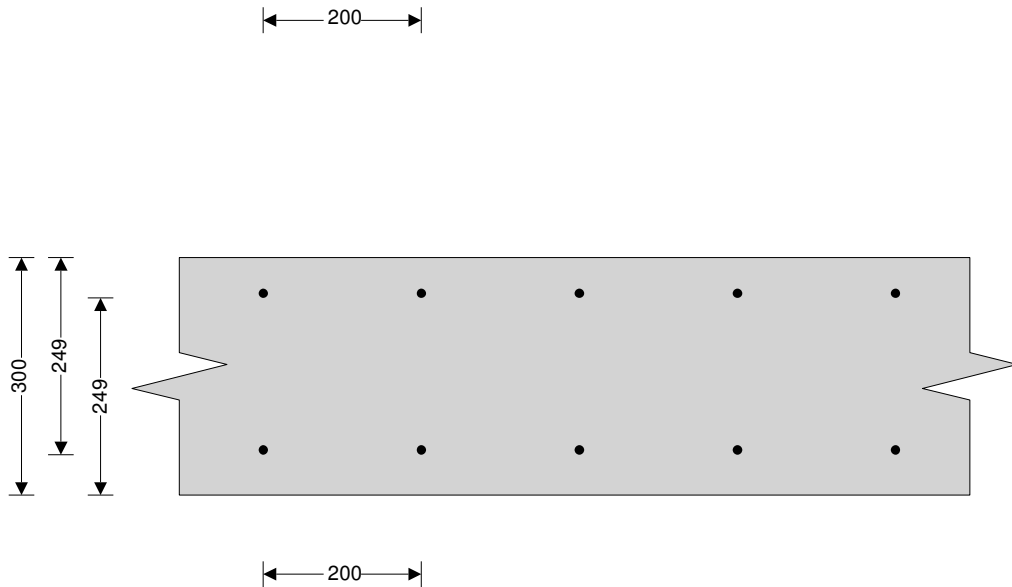
Water

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

Total moment for wall design

$$M_{wall} = M_{w\_sur} + M_{w\_s} + M_{w\_water} = \mathbf{17.8 \text{ kNm/m}}$$

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### Check wall stem in bending

Width of wall stem

$$b = 1000 \text{ mm/m}$$

Depth of reinforcement

$$d_{\text{stem}} = t_{\text{wall}} - c_{\text{stem}} - (\phi_{\text{stem}} / 2) = 249.0 \text{ mm}$$

Constant

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

**Compression reinforcement is not required**

Lever arm

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

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

Area of tension reinforcement required

$$A_{\text{s\_stem\_des}} = M_{\text{stem}} / (0.87 \times f_y \times z_{\text{stem}}) = 363 \text{ mm}^2/\text{m}$$

Minimum area of tension reinforcement

$$A_{\text{s\_stem\_min}} = k \times b \times t_{\text{wall}} = 390 \text{ mm}^2/\text{m}$$

Area of tension reinforcement required

$$A_{\text{s\_stem\_req}} = \text{Max}(A_{\text{s\_stem\_des}}, A_{\text{s\_stem\_min}}) = 390 \text{ mm}^2/\text{m}$$

Reinforcement provided

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

Area of reinforcement provided

$$A_{\text{s\_stem\_prov}} = 565 \text{ mm}^2/\text{m}$$

**PASS - Reinforcement provided at the retaining wall stem is adequate**

### Check shear resistance at wall stem

Design shear stress

$$v_{\text{stem}} = V_{\text{stem}} / (b \times d_{\text{stem}}) = 0.313 \text{ N/mm}^2$$

Allowable shear stress

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

**PASS - Design shear stress is less than maximum shear stress**

### From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress

$$v_{\text{c\_stem}} = 0.508 \text{ N/mm}^2$$

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

### Check mid height of wall in bending

Depth of reinforcement

$$d_{\text{wall}} = t_{\text{wall}} - c_{\text{wall}} - (\phi_{\text{wall}} / 2) = 249.0 \text{ mm}$$

Constant

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

**Compression reinforcement is not required**

Lever arm

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

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

Area of tension reinforcement required

$$A_{\text{s\_wall\_des}} = M_{\text{wall}} / (0.87 \times f_y \times z_{\text{wall}}) = 173 \text{ mm}^2/\text{m}$$

Minimum area of tension reinforcement

$$A_{\text{s\_wall\_min}} = k \times b \times t_{\text{wall}} = 390 \text{ mm}^2/\text{m}$$

Area of tension reinforcement required

$$A_{\text{s\_wall\_req}} = \text{Max}(A_{\text{s\_wall\_des}}, A_{\text{s\_wall\_min}}) = 390 \text{ mm}^2/\text{m}$$





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Reinforcement provided

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

Area of reinforcement provided

$A_{s\_wall\_prov} = 565 \text{ mm}^2/\text{m}$

**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

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

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

$ratio_{max} = ratio_{bas} \times factor_{tens} = 38.42$

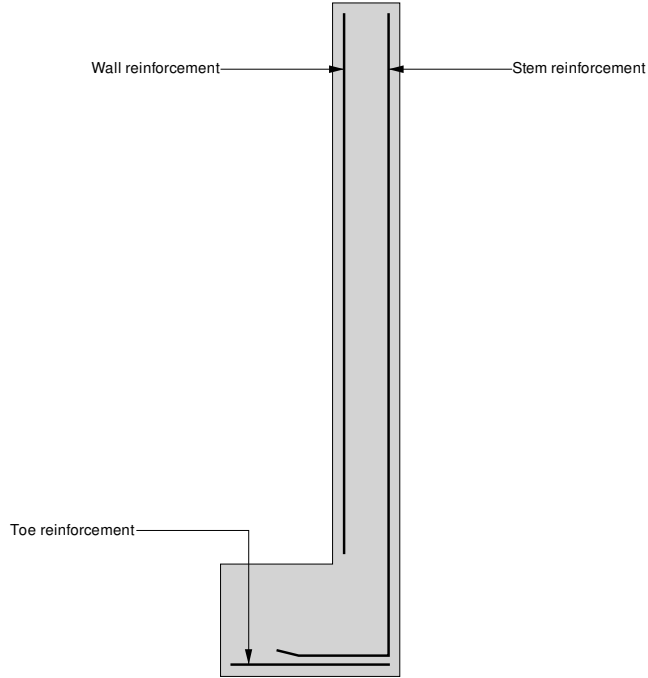
Actual span/effective depth ratio

$ratio_{act} = h_{stem} / d_{stem} = 10.04$

**PASS - Span to depth ratio is acceptable**

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**Indicative retaining wall reinforcement diagram**



Toe bars - 16 mm dia.@ 200 mm centres - (1005 mm<sup>2</sup>/m)

Wall bars - 12 mm dia.@ 200 mm centres - (565 mm<sup>2</sup>/m)

Stem bars - 12 mm dia.@ 200 mm centres - (565 mm<sup>2</sup>/m)

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Job title: 10 Downside Crescent			
Calculations: Load on side wall top beam	Designed: ab	Date: 11/10/2016	Ckd: -

Horizontal load on side wall top beam

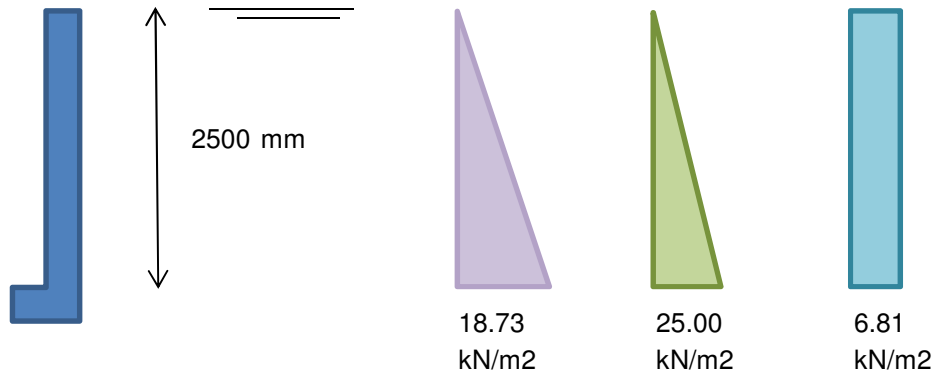
At rest. pressure coefficient

K0      0.681

Sat. backfill      Water density      Surcharge  
21      kN/m<sup>3</sup>      10      kN/m<sup>3</sup>      10      kN/m<sup>2</sup>

basement level

It is assumed max water table



Reaction at top and base of retaining wall  
assuming 1m length

TOP	7.8031 kN/m	10.417 kN/m	8.5125 kN/m
BASE	15.606 kN/m	20.833 kN/m	8.5125 kN/m

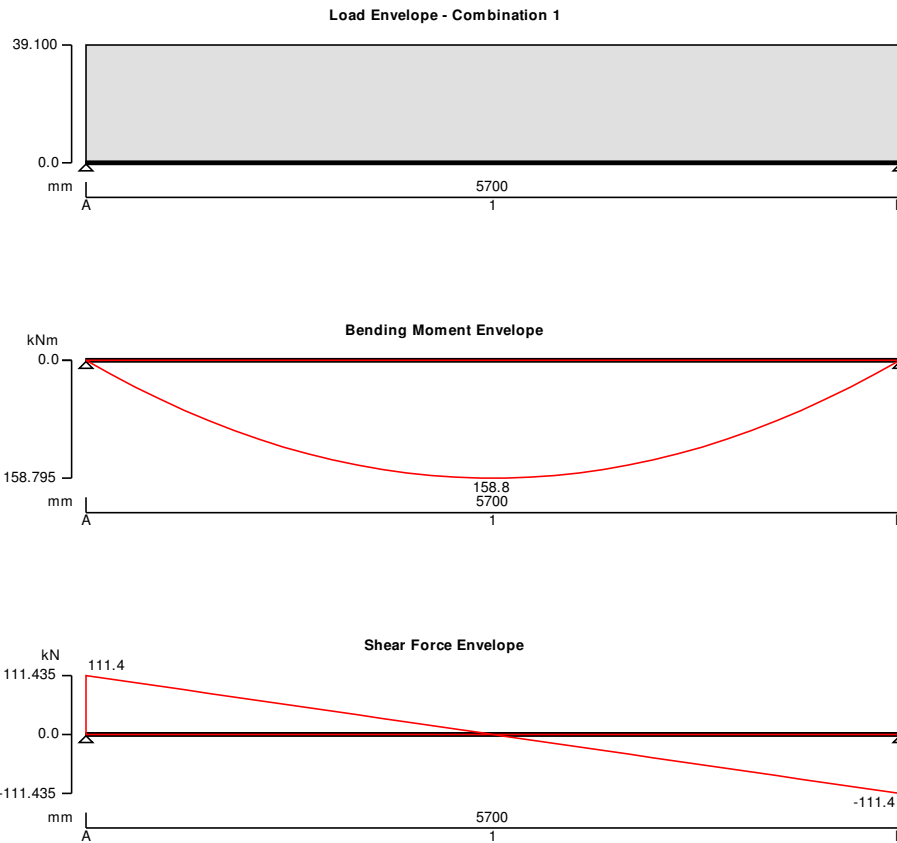
Ultimate reaction on underpinning  
( 1,4xDEAD+1,6xIMPOSED )

TOP	<b>39.1 kN/m</b>
BASE	<b>64.6 kN/m</b>

Project <b>10 Downside Crescent</b>				Job no. <b>1411</b>	
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**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  $\times 0$   
Dead full UDL 39.1 kN/m

**Load combinations**

Load combination 1	Support A	Dead $\times 1.00$ Imposed $\times 1.00$
	Span 1	Dead $\times 1.00$ Imposed $\times 1.00$
	Support B	Dead $\times 1.00$ Imposed $\times 1.00$

**Analysis results**

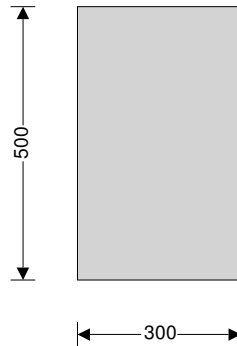
Maximum moment support A	$M_{A\_max} = 0$ kNm	$M_{A\_red} = 0$ kNm
Maximum moment span 1 at 2850 mm	$M_{s1\_max} = 159$ kNm	$M_{s1\_red} = 159$ kNm

Project <b>10 Downside Crescent</b>				Job no. <b>1411</b>	
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Maximum moment support B	$M_{B\_max} = 0 \text{ kNm}$	$M_{B\_red} = 0 \text{ kNm}$
Maximum shear support A	$V_{A\_max} = 111 \text{ kN}$	$V_{A\_red} = 111 \text{ kN}$
Maximum shear support A span 1 at 447 mm	$V_{A\_s1\_max} = 94 \text{ kN}$	$V_{A\_s1\_red} = 94 \text{ kN}$
Maximum shear support B	$V_{B\_max} = -111 \text{ kN}$	$V_{B\_red} = -111 \text{ kN}$
Maximum shear support B span 1 at 5253 mm	$V_{B\_s1\_max} = -94 \text{ kN}$	$V_{B\_s1\_red} = -94 \text{ kN}$
Maximum reaction at support A	$R_A = 111 \text{ kN}$	
Unfactored dead load reaction at support A	$R_{A\_Dead} = 111 \text{ kN}$	
Maximum reaction at support B	$R_B = 111 \text{ kN}$	
Unfactored dead load reaction at support B	$R_{B\_Dead} = 111 \text{ kN}$	

### Rectangular section details

Section width	$b = 300 \text{ mm}$
Section depth	$h = 500 \text{ mm}$



### Concrete details

Concrete strength class	<b>C32/40</b>
Characteristic compressive cube strength	$f_{cu} = 40 \text{ N/mm}^2$
Modulus of elasticity of concrete	$E_c = 20 \text{ kN/mm}^2 + 200 \times f_{cu} = 28000 \text{ N/mm}^2$
Maximum aggregate size	$h_{agg} = 20 \text{ mm}$

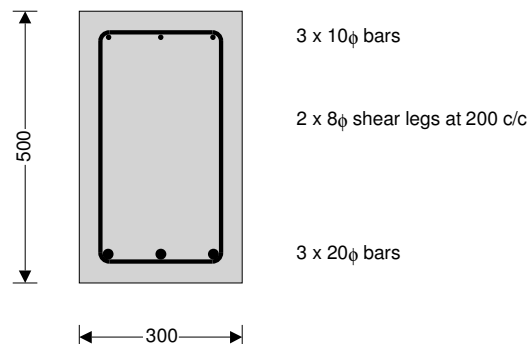
### Reinforcement details


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

### Nominal cover to reinforcement

Nominal cover to top reinforcement	$C_{nom\_t} = 35 \text{ mm}$
Nominal cover to bottom reinforcement	$C_{nom\_b} = 35 \text{ mm}$
Nominal cover to side reinforcement	$C_{nom\_s} = 35 \text{ mm}$

### Support A



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### Rectangular section in shear

Design shear force span 1 at 447 mm

$$V = \max(V_{A_{s1\_max}}, V_{A_{s1\_red}}) = \mathbf{94 \text{ kN}}$$

Design shear stress

$$v = V / (b \times d) = \mathbf{0.700 \text{ N/mm}^2}$$

Design concrete shear stress

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

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

$$v_c = \mathbf{0.657 \text{ N/mm}^2}$$

Allowable design shear stress

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

**PASS - Design shear stress is less than maximum allowable**

Value of  $v$  from Table 3.7

$$0.5 \times v_c < v < (v_c + 0.4 \text{ N/mm}^2)$$

Design shear resistance required

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

Area of shear reinforcement required

$$A_{sv,req} = v_s \times b / (0.87 \times f_{yv}) = \mathbf{276 \text{ mm}^2/\text{m}}$$

Shear reinforcement provided

$$2 \times 8\phi \text{ legs at } 200 \text{ c/c}$$

Area of shear reinforcement provided

$$A_{sv,prov} = \mathbf{503 \text{ mm}^2/\text{m}}$$

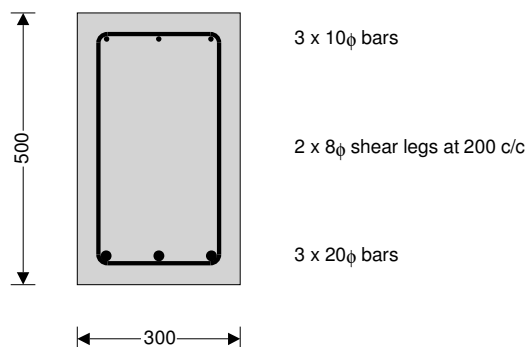
**PASS - Area of shear reinforcement provided exceeds minimum required**

Maximum longitudinal spacing

$$s_{vl,max} = 0.75 \times d = \mathbf{335 \text{ mm}}$$

**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

$$M = \text{abs}(M_{s1\_red}) = \mathbf{159 \text{ kNm}}$$

Depth to tension reinforcement

$$d = h - c_{nom\_b} - \phi_v - \phi_{bot} / 2 = \mathbf{447 \text{ mm}}$$

Redistribution ratio

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

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

$$K' = 0.156$$

**K' > K - No compression reinforcement is required**

Lever arm

$$z = \min(d \times (0.5 + (0.25 - K / 0.9)^{0.5}), 0.95 \times d) = \mathbf{411 \text{ mm}}$$

Depth of neutral axis

$$x = (d - z) / 0.45 = \mathbf{79 \text{ mm}}$$

Area of tension reinforcement required

$$A_{s,req} = M / (0.87 \times f_y \times z) = \mathbf{888 \text{ mm}^2}$$

Tension reinforcement provided

$$3 \times 20\phi \text{ bars}$$

Area of tension reinforcement provided

$$A_{s,prov} = \mathbf{942 \text{ mm}^2}$$

Minimum area of reinforcement

$$A_{s,min} = 0.0013 \times b \times h = \mathbf{195 \text{ mm}^2}$$

Maximum area of reinforcement

$$A_{s,max} = 0.04 \times b \times h = \mathbf{6000 \text{ mm}^2}$$

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


### Rectangular section in shear

Shear reinforcement provided

$$2 \times 8\phi \text{ legs at } 200 \text{ c/c}$$

Area of shear reinforcement provided

$$A_{sv,prov} = \mathbf{503 \text{ mm}^2/\text{m}}$$

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

**PASS - Area of shear reinforcement provided exceeds minimum required**

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

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

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

Design shear resistance provided  $V_{s,prov} = A_{sv,prov} \times 0.87 \times f_{yv} / b = 0.729 \text{ N/mm}^2$

Design shear stress provided  $V_{prov} = V_{s,prov} + V_c = 1.386 \text{ N/mm}^2$

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

**Shear links provided valid between 0 mm and 5700 mm with tension reinforcement of 942 mm<sup>2</sup>**

### Spacing of reinforcement (cl 3.12.11)

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

### Minimum distance between bars in tension (cl 3.12.11.1)

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

**PASS - Satisfies the minimum spacing criteria**

### Maximum distance between bars in tension (cl 3.12.11.2)

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

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

**PASS - Satisfies the maximum spacing criteria**

### Span to depth ratio (cl. 3.4.6)

Basic span to depth ratio (Table 3.9)  $\text{span\_to\_depth}_{basic} = 20.0$

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

Modification for tension reinforcement

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

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

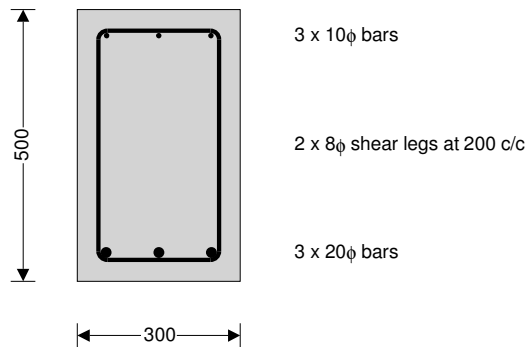
$$\text{span\_to\_depth}_{allow} = \text{span\_to\_depth}_{basic} \times f_{tens} \times f_{comp} = 19.7$$

Actual span to depth ratio

$$\text{span\_to\_depth}_{actual} = L_{s1} / d = 12.8$$

**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

$$V = \text{abs}(\min(V_{B,s1,max}, V_{B,s1,red})) = 94 \text{ kN}$$

Design shear stress

$$v = V / (b \times d) = 0.700 \text{ N/mm}^2$$




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Design concrete shear stress $(\min(f_{cu}, 40) / 25)^{1/3} / \gamma_m$	$v_c = 0.79 \times \min(3, [100 \times A_{s,prov} / (b \times d)]^{1/3}) \times \max(1, (400 / d)^{1/4}) \times$ $v_c = \mathbf{0.657} \text{ N/mm}^2$
Allowable design shear stress	$v_{max} = \min(0.8 \text{ N/mm}^2 \times (f_{cu}/1 \text{ N/mm}^2)^{0.5}, 5 \text{ N/mm}^2) = \mathbf{5.000} \text{ N/mm}^2$ <b>PASS - Design shear stress is less than maximum allowable</b>
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	$v_s = \max(v - v_c, 0.4 \text{ N/mm}^2) = \mathbf{0.400} \text{ N/mm}^2$
Area of shear reinforcement required	$A_{sv,req} = v_s \times b / (0.87 \times f_{yv}) = \mathbf{276} \text{ mm}^2/\text{m}$
Shear reinforcement provided	$2 \times 8\phi$ legs at 200 c/c
Area of shear reinforcement provided	$A_{sv,prov} = \mathbf{503} \text{ mm}^2/\text{m}$ <b>PASS - Area of shear reinforcement provided exceeds minimum required</b>
Maximum longitudinal spacing	$s_{vl,max} = 0.75 \times d = \mathbf{335} \text{ mm}$ <b>PASS - Longitudinal spacing of shear reinforcement provided is less than maximum</b>



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## RC SLAB DESIGN (BS8110:PART1:1997)

TEDDS calculation version 1.0.04

### TWO WAY SPANNING SLAB DEFINITION – SIMPLY SUPPORTED

Overall depth of slab  $h = 175$  mm

Outer sagging steel

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

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

Depth to outer tension steel (resisting sagging)

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

Inner sagging steel

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

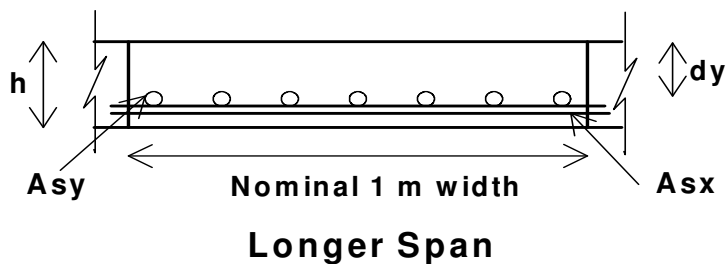
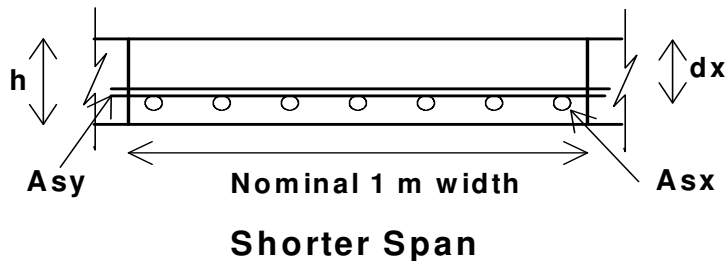
Depth to inner tension steel (resisting sagging)

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

Materials

Characteristic strength of reinforcement  $f_y = 500$  N/mm<sup>2</sup>

Characteristic strength of concrete  $f_{cu} = 40$  N/mm<sup>2</sup>



### **Two-way spanning slab (simple)**

#### MAXIMUM DESIGN MOMENTS

Length of shorter side of slab  $l_x = 3.500$  m

Length of longer side of slab  $l_y = 6.400$  m

Design ultimate load per unit area  $n_s = 12.9$  kN/m<sup>2</sup>

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#### Moment coefficients

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

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

#### Maximum moments per unit width - simply supported slabs

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

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

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

Design sagging moment (per m width of slab)  $m_{sx} = \mathbf{18.1 \text{ kNm/m}}$

Moment Redistribution Factor  $\beta_{bx} = \mathbf{1.0}$

#### **Area of reinforcement required**

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

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

*Outer compression steel not required to resist sagging*

#### **Slab requiring outer tension steel only - bars (sagging)**

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

$$\text{Neutral axis depth } x_x = (d_x - z_x) / 0.45 = \mathbf{16 \text{ mm}}$$

#### Area of tension steel required

$$A_{sx\_req} = \text{abs}(m_{sx}) / (1/\gamma_{ms} \times f_y \times z_x) = \mathbf{305 \text{ mm}^2/\text{m}}$$

#### Tension steel

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

$$A_{sx\_prov} = A_{sx} = \mathbf{565 \text{ mm}^2/\text{m}}$$

*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)  $m_{sy} = \mathbf{5.4 \text{ kNm/m}}$

Moment Redistribution Factor  $\beta_{by} = \mathbf{1.0}$

#### **Area of reinforcement required**

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

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


*Inner compression steel not required to resist sagging*

#### **Slab requiring inner tension steel only - bars (sagging)**

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

$$\text{Neutral axis depth } x_y = (d_y - z_y) / 0.45 = \mathbf{15 \text{ mm}}$$

#### Area of tension steel required

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$$A_{sy\_req} = \text{abs}(m_{sy}) / (1/\gamma_{ms} \times f_y \times z_y) = 99 \text{ mm}^2/\text{m}$$

### Tension steel

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

$$A_{sy\_prov} = A_{sy} = 565 \text{ mm}^2/\text{m}$$

**Area of inner tension steel provided sufficient to resist sagging**

**Check min and max areas of steel resisting sagging**

$$\text{Total area of concrete } A_c = h = 175000 \text{ mm}^2/\text{m}$$

$$\text{Minimum \% reinforcement } k = 0.13 \%$$

$$A_{st\_min} = k \times A_c = 228 \text{ mm}^2/\text{m}$$

$$A_{st\_max} = 4 \% \times A_c = 7000 \text{ mm}^2/\text{m}$$

Steel defined:

$$\text{Outer steel resisting sagging } A_{sx\_prov} = 565 \text{ mm}^2/\text{m}$$

**Area of outer steel provided (sagging) OK**

$$\text{Inner steel resisting sagging } A_{sy\_prov} = 565 \text{ mm}^2/\text{m}$$

**Area of inner steel provided (sagging) OK**

### **SHEAR RESISTANCE OF CONCRETE SLABS (CL 3.5.5)**

#### **Outer tension steel resisting sagging moments**

$$\text{Depth to tension steel from compression face } d_x = 144 \text{ mm}$$

$$\text{Area of tension reinforcement provided (per m width of slab) } A_{sx\_prov} = 565 \text{ mm}^2/\text{m}$$

$$\text{Design ultimate shear force (per m width of slab) } V_x = 41 \text{ kN/m}$$

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

#### **Applied shear stress**

$$v_x = V_x / d_x = 0.29 \text{ N/mm}^2$$

#### **Check shear stress to clause 3.5.5.2**

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

**Shear stress - OK**

#### **Shear stresses to clause 3.5.5.3**

##### **Design shear stress**

$$f_{cu\_ratio} = \text{if } (f_{cu} > 40 \text{ N/mm}^2, 40/25, f_{cu}/(25 \text{ N/mm}^2)) = 1.600$$


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

$$v_{cx} = 0.70 \text{ N/mm}^2$$

Applied shear stress

$$v_x = 0.29 \text{ N/mm}^2$$

**No shear reinforcement required**

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### **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)  $A_{sy\_prov} = 565$  mm<sup>2</sup>/m

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

Characteristic strength of concrete  $f_{cu} = 40$  N/mm<sup>2</sup>

#### **Applied shear stress**

$$v_y = V_y / d_y = 0.20 \text{ N/mm}^2$$

#### **Check shear stress to clause 3.5.5.2**

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

**Shear stress - OK**

#### **Shear stresses to clause 3.5.5.3**

##### **Design shear stress**

$$f_{cu\_ratio} = \text{if } (f_{cu} > 40 \text{ N/mm}^2, 40/25, f_{cu}/(25 \text{ N/mm}^2)) = 1.600$$

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

$$v_{cy} = 0.73 \text{ N/mm}^2$$

Applied shear stress

$$v_y = 0.20 \text{ N/mm}^2$$

**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  $A_{sx\_prov} = 565$  mm<sup>2</sup>/m

Area of tension reinforcement required  $A_{sx\_req} = 305$  mm<sup>2</sup>/m

Moment Redistribution Factor  $\beta_{bx} = 1.00$

#### **Modification Factors**


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

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

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

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

#### **Calculate Maximum Span**

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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.

$$\text{Maximum span } l_{\max} = \text{ratio}_{\text{span\_depth}} \times \text{factor}_{\text{tens}} \times d_x = \mathbf{5.60 \text{ m}}$$

**Check the actual beam span**

$$\text{Actual span/depth ratio } l_x / d_x = \mathbf{24.31}$$

$$\text{Span depth limit } \text{ratio}_{\text{span\_depth}} \times \text{factor}_{\text{tens}} = \mathbf{38.91}$$

***Span/Depth ratio check satisfied***

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

$$\text{Slab thickness } h = \mathbf{175 \text{ mm}}$$

$$\text{Effective depth to bottom outer tension reinforcement } d_x = \mathbf{144.0 \text{ mm}}$$

$$\text{Diameter of tension reinforcement } D_x = \mathbf{12 \text{ mm}}$$

$$\text{Diameter of links } L_{\text{diax}} = \mathbf{0 \text{ mm}}$$

Cover to outer tension reinforcement

$$C_{\text{tenx}} = h - d_x - D_x / 2 = \mathbf{25.0 \text{ mm}}$$

Nominal cover to links steel

$$C_{\text{nomx}} = C_{\text{tenx}} - L_{\text{diax}} = \mathbf{25.0 \text{ mm}}$$

Permissible minimum nominal cover to all reinforcement (Table 3.4)

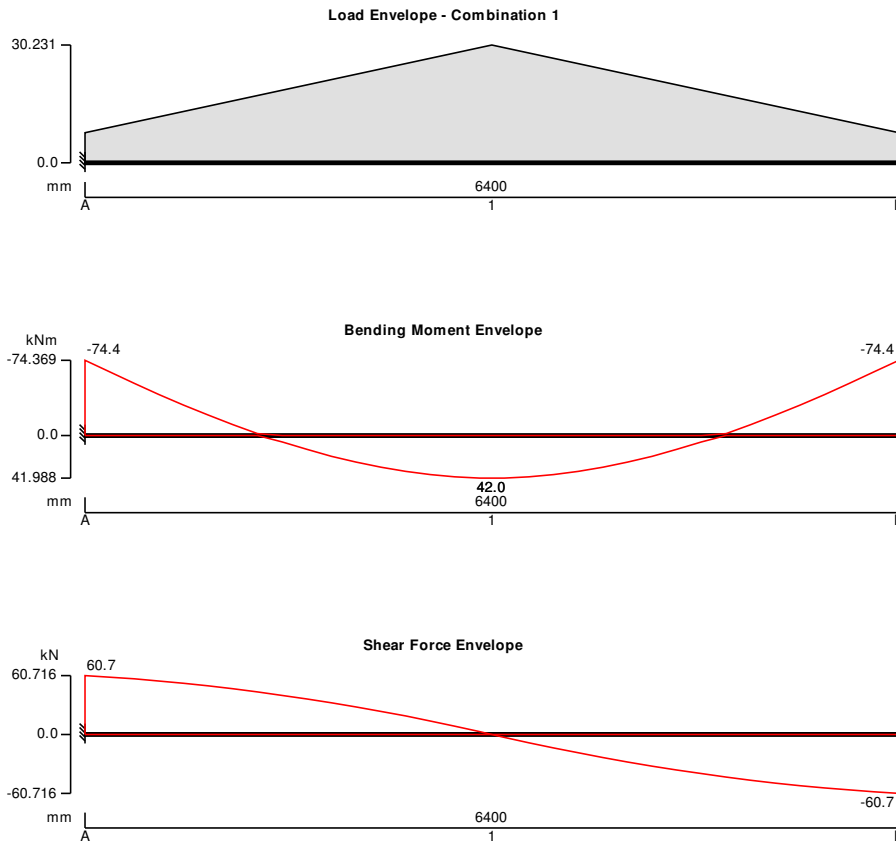
$$C_{\text{min}} = \mathbf{25 \text{ mm}}$$

***Cover over steel resisting sagging OK***

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**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  $\times 1$
- 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 $\times 1.40$ Imposed $\times 1.60$
	Span 1	Dead $\times 1.40$ Imposed $\times 1.60$
	Support B	Dead $\times 1.40$ Imposed $\times 1.60$

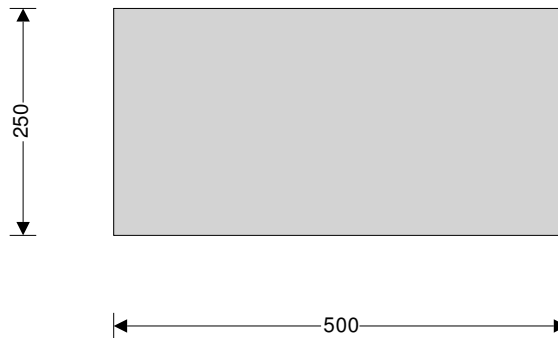
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### Analysis results

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	<b>C32/40</b>
Characteristic compressive cube strength	$f_{cu} = 40$ N/mm <sup>2</sup>
Modulus of elasticity of concrete	$E_c = 20\text{kN/mm}^2 + 200 \times f_{cu} = 28000$ N/mm <sup>2</sup>
Maximum aggregate size	$h_{agg} = 20$ mm

### Reinforcement details

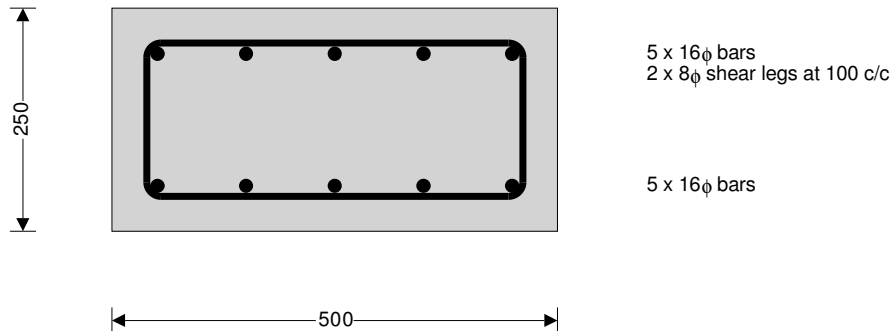
Characteristic yield strength of reinforcement	$f_y = 500$ N/mm <sup>2</sup>
Characteristic yield strength of shear reinforcement	$f_{yv} = 500$ N/mm <sup>2</sup>

### 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

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### Support A



### Rectangular section in flexure (cl.3.4.4)

Design bending moment	$M = \text{abs}(M_{A\_red}) = 74 \text{ kNm}$
Depth to tension reinforcement	$d = h - c_{nom\_t} - \phi_v - \phi_{top} / 2 = 199 \text{ mm}$
Redistribution ratio	$\beta_b = \min(1 - m_{rA}, 1) = 1.000$
	$K = M / (b \times d^2 \times f_{cu}) = 0.094$
	$K' = 0.156$

***K' > K - No compression reinforcement is required***

Lever arm	$z = \min(d \times (0.5 + (0.25 - K / 0.9)^{0.5}), 0.95 \times d) = 175 \text{ mm}$
Depth of neutral axis	$x = (d - z) / 0.45 = 52 \text{ mm}$
Area of tension reinforcement required	$A_{s,req} = M / (0.87 \times f_y \times z) = 974 \text{ mm}^2$
Tension reinforcement provided	5 × 16φ bars
Area of tension reinforcement provided	$A_{s,prov} = 1005 \text{ mm}^2$
Minimum area of reinforcement	$A_{s,min} = 0.0013 \times b \times h = 163 \text{ mm}^2$
Maximum area of reinforcement	$A_{s,max} = 0.04 \times b \times h = 5000 \text{ mm}^2$

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

### Rectangular section in shear

Design shear force span 1 at 199 mm	$V = \max(V_{A\_s1\_max}, V_{A\_s1\_red}) = 59 \text{ kN}$
Design shear stress	$v = V / (b \times d) = 0.593 \text{ N/mm}^2$
Design concrete shear stress ( $\min(f_{cu}, 40) / 25$ ) <sup>1/3</sup> / $\gamma_m$	$v_c = 0.79 \times \min(3, [100 \times A_{s,prov} / (b \times d)]^{1/3}) \times \max(1, (400 / d)^{1/4}) \times$ $v_c = 0.883 \text{ N/mm}^2$
Allowable design shear stress	$v_{max} = \min(0.8 \text{ N/mm}^2 \times (f_{cu} / 1 \text{ N/mm}^2)^{0.5}, 5 \text{ N/mm}^2) = 5.000 \text{ N/mm}^2$

***PASS - Design shear stress is less than maximum allowable***

Value of v from Table 3.7	$0.5 \times v_c < v < (v_c + 0.4 \text{ N/mm}^2)$
Design shear resistance required	$v_s = \max(v - v_c, 0.4 \text{ N/mm}^2) = 0.400 \text{ N/mm}^2$
Area of shear reinforcement required	$A_{sv,req} = v_s \times b / (0.87 \times f_{yv}) = 460 \text{ mm}^2/\text{m}$
Shear reinforcement provided	2 × 8φ legs at 100 c/c
Area of shear reinforcement provided	$A_{sv,prov} = 1005 \text{ mm}^2/\text{m}$

***PASS - Area of shear reinforcement provided exceeds minimum required***


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

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

### Spacing of reinforcement (cl 3.12.11)

Actual distance between bars in tension	$s = (b - 2 \times (c_{nom\_s} + \phi_v + \phi_{top}/2)) / (N_{top} - 1) - \phi_{top} = 84 \text{ mm}$
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### Minimum distance between bars in tension (cl 3.12.11.1)

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

**PASS - Satisfies the minimum spacing criteria**

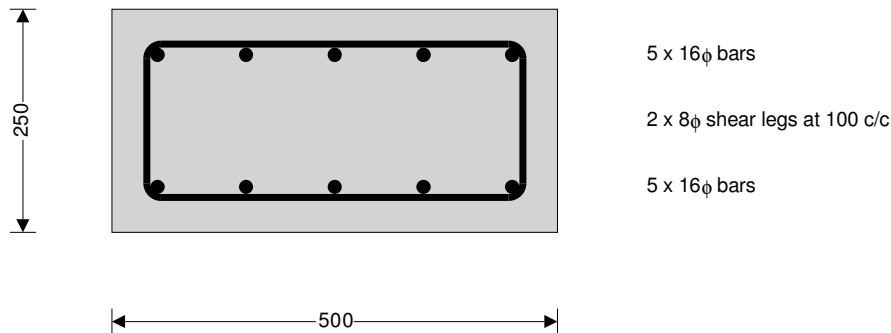
### Maximum distance between bars in tension (cl 3.12.11.2)

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

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

**PASS - Satisfies the maximum spacing criteria**

### Mid span 1



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

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

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

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

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

$K' = 0.156$

**$K' > K$  - No compression reinforcement is required**

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

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

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

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

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

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

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

**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  $A_{sv,prov} = 1005 \text{ mm}^2/\text{m}$

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

**PASS - Area of shear reinforcement provided exceeds minimum required**

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


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

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

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

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

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

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**Shear links provided valid between 0 mm and 6400 mm with tension reinforcement of 1005 mm<sup>2</sup>**

**Spacing of reinforcement (cl 3.12.11)**

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

**Minimum distance between bars in tension (cl 3.12.11.1)**

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

**PASS - Satisfies the minimum spacing criteria**

**Maximum distance between bars in tension (cl 3.12.11.2)**

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

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

**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  $f_s = (2 \times f_y \times A_{s,req}) / (3 \times A_{s,prov} \times \beta_b) = 171.6 \text{ N/mm}^2$

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

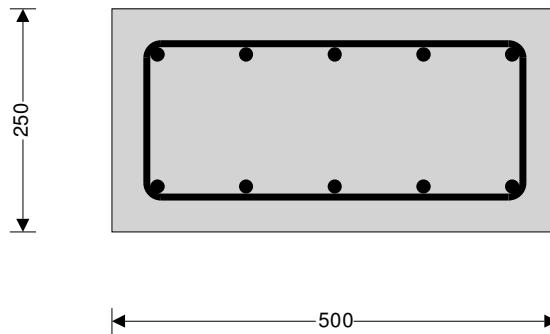
$$span\_to\_depth_{allow} = span\_to\_depth_{basic} \times f_{tens} \times f_{comp} = 34.9$$

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**



5 x 16 $\phi$  bars

2 x 8 $\phi$  shear legs at 100 c/c

5 x 16 $\phi$  bars

**Rectangular section in flexure (cl.3.4.4)**

Design bending moment

$$M = \text{abs}(M_{B\_red}) = 74 \text{ kNm}$$

Depth to tension reinforcement

$$d = h - C_{nom\_t} - \phi_v - \phi_{top} / 2 = 199 \text{ mm}$$

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

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

Depth of neutral axis

$$x = (d - z) / 0.45 = 52 \text{ mm}$$

Area of tension reinforcement required

$$A_{s,req} = M / (0.87 \times f_y \times z) = 974 \text{ mm}^2$$

Tension reinforcement provided


$$5 \times 16\phi \text{ bars}$$

Area of tension reinforcement provided

$$A_{s,prov} = 1005 \text{ mm}^2$$

Minimum area of reinforcement

$$A_{s,min} = 0.0013 \times b \times h = 163 \text{ mm}^2$$

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Maximum area of reinforcement

$$A_{s,max} = 0.04 \times b \times h = 5000 \text{ mm}^2$$

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

**Rectangular section in shear**

Design shear force span 1 at 6201 mm

$$V = \text{abs}(\min(V_{B_{s1\_max}}, V_{B_{s1\_red}})) = 59 \text{ kN}$$

Design shear stress

$$v = V / (b \times d) = 0.593 \text{ N/mm}^2$$

Design concrete shear stress

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

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

$$v_c = 0.883 \text{ N/mm}^2$$

Allowable design shear stress

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

**PASS - Design shear stress is less than maximum allowable**

Value of v from Table 3.7

$$0.5 \times v_c < v < (v_c + 0.4 \text{ N/mm}^2)$$

Design shear resistance required

$$v_s = \max(v - v_c, 0.4 \text{ N/mm}^2) = 0.400 \text{ N/mm}^2$$

Area of shear reinforcement required

$$A_{sv,req} = v_s \times b / (0.87 \times f_{yv}) = 460 \text{ mm}^2/\text{m}$$

Shear reinforcement provided

$$2 \times 8\phi \text{ legs at } 100 \text{ c/c}$$

Area of shear reinforcement provided

$$A_{sv,prov} = 1005 \text{ mm}^2/\text{m}$$

**PASS - Area of shear reinforcement provided exceeds minimum required**

Maximum longitudinal spacing

$$s_{vl,max} = 0.75 \times d = 149 \text{ mm}$$

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

**Spacing of reinforcement (cl 3.12.11)**

Actual distance between bars in tension

$$s = (b - 2 \times (c_{nom\_s} + \phi_v + \phi_{top}/2)) / (N_{top} - 1) - \phi_{top} = 84 \text{ mm}$$

**Minimum distance between bars in tension (cl 3.12.11.1)**

Minimum distance between bars in tension

$$s_{min} = h_{agg} + 5 \text{ mm} = 25 \text{ mm}$$

**PASS - Satisfies the minimum spacing criteria**

**Maximum distance between bars in tension (cl 3.12.11.2)**

Design service stress

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

Maximum distance between bars in tension

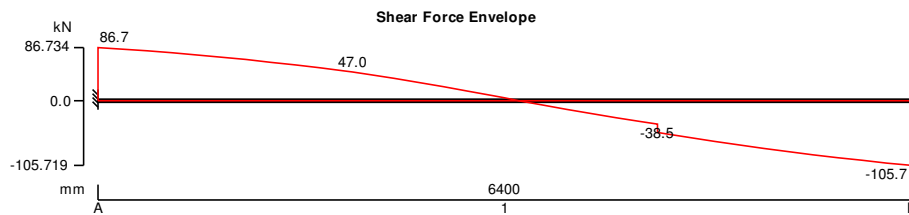
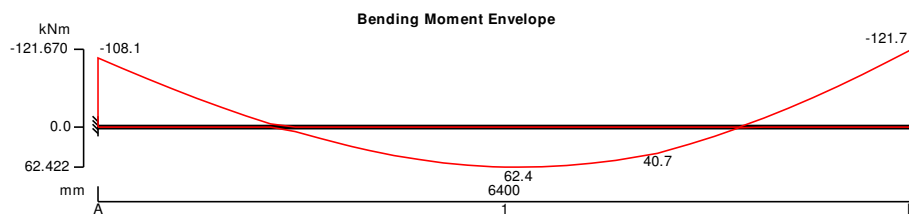
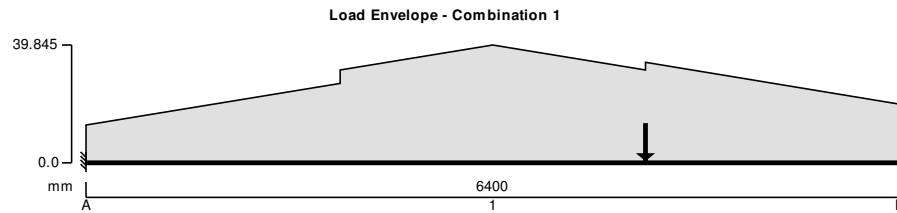
$$s_{max} = \min(47000 \text{ N/mm} / f_s, 300 \text{ mm}) = 145 \text{ mm}$$

**PASS - Satisfies the maximum spacing criteria**

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**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  $\times 1$
- 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 $\times 1.40$ Imposed $\times 1.60$
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Span 1  
Dead × 1.40  
Imposed × 1.60

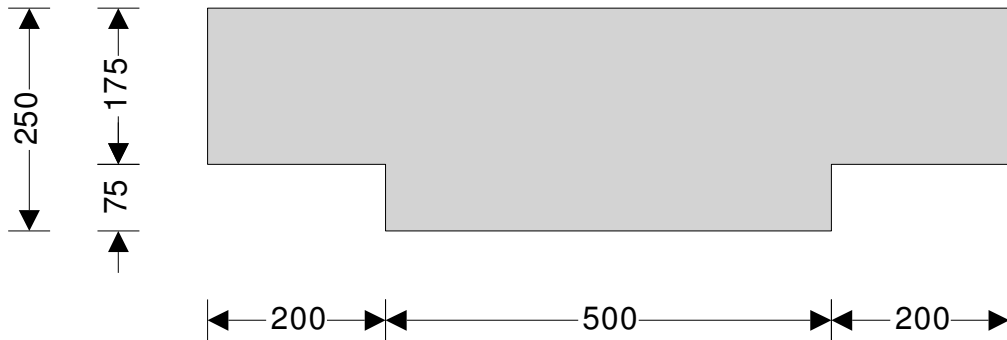
Support B  
Dead × 1.40  
Imposed × 1.60

### 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	<b>C32/40</b>
Characteristic compressive cube strength	$f_{cu} = 40$ N/mm <sup>2</sup>
Modulus of elasticity of concrete	$E_c = 20\text{kN/mm}^2 + 200 \times f_{cu} = 28000$ N/mm <sup>2</sup>
Maximum aggregate size	$h_{agg} = 20$ mm

### Reinforcement details

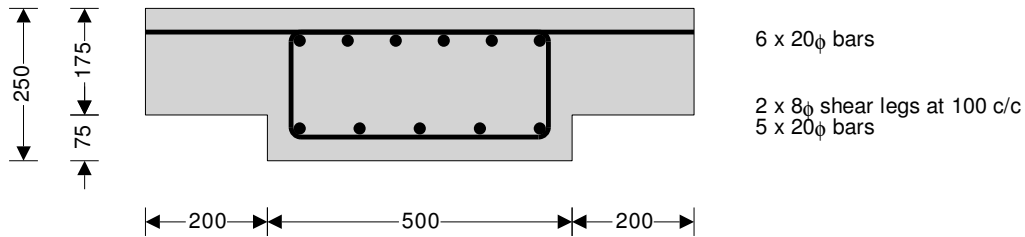
Characteristic yield strength of reinforcement	$f_y = 500$ N/mm <sup>2</sup>
Characteristic yield strength of shear reinforcement	$f_{yv} = 500$ N/mm <sup>2</sup>

### 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

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### Support A



### Rectangular section in flexure (cl.3.4.4)

Design bending moment	$M = \text{abs}(M_{A\_red}) = 108 \text{ kNm}$
Depth to tension reinforcement	$d = h - C_{nom\_t} - \phi_v - \phi_{top} / 2 = 197 \text{ mm}$
Redistribution ratio	$\beta_b = \min(1 - m_{rA}, 1) = 1.000$
	$K = M / (b \times d^2 \times f_{cu}) = 0.139$
	$K' = 0.156$
	<b><math>K' &gt; K</math> - No compression reinforcement is required</b>

Lever arm	$z = \min(d \times (0.5 + (0.25 - K / 0.9)^{0.5}), 0.95 \times d) = 159 \text{ mm}$
Depth of neutral axis	$x = (d - z) / 0.45 = 84 \text{ mm}$
Area of tension reinforcement required	$A_{s,req} = M / (0.87 \times f_y \times z) = 1559 \text{ mm}^2$
Tension reinforcement provided	6 x 20φ bars
Area of tension reinforcement provided	$A_{s,prov} = 1885 \text{ mm}^2$
Minimum area of reinforcement	$A_{s,min} = 0.0013 \times b \times h = 163 \text{ mm}^2$
Maximum area of reinforcement	$A_{s,max} = 0.04 \times b \times h = 5000 \text{ mm}^2$

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

### Rectangular section in shear

Design shear force span 1 at 197 mm	$V = \max(V_{A\_s1\_max}, V_{A\_s1\_red}) = 84 \text{ kN}$
Design shear stress	$v = V / (b \times d) = 0.854 \text{ N/mm}^2$
Design concrete shear stress	$v_c = 0.79 \times \min(3, [100 \times A_{s,prov} / (b \times d)]^{1/3}) \times \max(1, (400 / d)^{1/4}) \times$
$(\min(f_{cu}, 40) / 25)^{1/3} / \gamma_m$	$v_c = 1.095 \text{ N/mm}^2$
Allowable design shear stress	$v_{max} = \min(0.8 \text{ N/mm}^2 \times (f_{cu} / 1 \text{ N/mm}^2)^{0.5}, 5 \text{ N/mm}^2) = 5.000 \text{ N/mm}^2$
	<b>PASS - Design shear stress is less than maximum allowable</b>

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	$v_s = \max(v - v_c, 0.4 \text{ N/mm}^2) = 0.400 \text{ N/mm}^2$
Area of shear reinforcement required	$A_{sv,req} = v_s \times b / (0.87 \times f_{yv}) = 460 \text{ mm}^2/\text{m}$
Shear reinforcement provided	2 x 8φ legs at 100 c/c
Area of shear reinforcement provided	$A_{sv,prov} = 1005 \text{ mm}^2/\text{m}$
	<b>PASS - Area of shear reinforcement provided exceeds minimum required</b>

Maximum longitudinal spacing	$s_{vl,max} = 0.75 \times d = 148 \text{ mm}$
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**PASS - Longitudinal spacing of shear reinforcement provided is less than maximum**


### Spacing of reinforcement (cl 3.12.11)

Actual distance between bars in tension	$s = (b - 2 \times (C_{nom\_s} + \phi_v + \phi_{top}/2)) / (N_{top} - 1) - \phi_{top} = 59 \text{ mm}$
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### Minimum distance between bars in tension (cl 3.12.11.1)

Minimum distance between bars in tension	$s_{min} = h_{agg} + 5 \text{ mm} = 25 \text{ mm}$
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**PASS - Satisfies the minimum spacing criteria**

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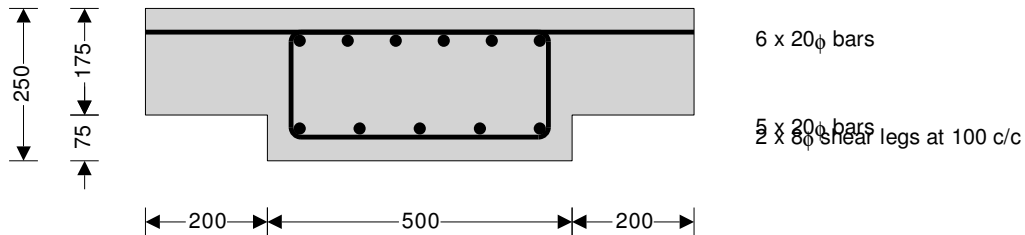
### Maximum distance between bars in tension (cl 3.12.11.2)

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

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

**PASS - Satisfies the maximum spacing criteria**

### Mid span 1



### Flanged section in flexure - Positive moment

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

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

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

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

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

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

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

$K' = 0.156 = 0.156$

**$K' > K$  - No compression reinforcement is required**

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

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

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

Tension reinforcement provided  $5 \times 20\phi \text{ bars}$

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

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

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

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

### Rectangular section in shear

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

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

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

**PASS - Area of shear reinforcement provided exceeds minimum required**

Maximum longitudinal spacing (cl. 3.4.5.5)  $s_{vl,max} = 0.75 \times d = 148 \text{ mm}$

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


Design concrete shear stress  $v_c = 0.79 \text{ N/mm}^2 \times \min(3, [100 \times A_{s,prov} / (b \times d)]^{1/3}) \times \max(1, (400 \text{ mm} / d)^{1/4}) \times (\min(f_{cu}, 40 \text{ N/mm}^2) / 25 \text{ N/mm}^2)^{1/3} / \gamma_m = 1.031 \text{ N/mm}^2$

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

Design shear stress provided  $V_{prov} = V_{s,prov} + v_c = 1.906 \text{ N/mm}^2$

Design shear resistance  $V_{prov} = V_{prov} \times (b \times d) = 187.7 \text{ kN}$

**Shear links provided valid between 0 mm and 6400 mm with tension reinforcement of 1571 mm<sup>2</sup>**

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### Spacing of reinforcement (cl 3.12.11)

Actual distance between bars in tension  $s = (b - 2 \times (C_{nom\_s} + \phi_v + \phi_{bot}/2)) / (N_{bot} - 1) - \phi_{bot} = 79 \text{ mm}$

### Minimum distance between bars in tension (cl 3.12.11.1)

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

**PASS - Satisfies the minimum spacing criteria**

### Maximum distance between bars in tension (cl 3.12.11.2)

Design service stress  $f_s = (2 \times f_y \times A_{s,req}) / (3 \times A_{s,prov} \times \beta_b) = 163.1 \text{ N/mm}^2$

Maximum distance between bars in tension  $s_{max} = \min(47000 \text{ N/mm} / f_s, 300 \text{ mm}) = 288 \text{ mm}$

**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  $f_s = (2 \times f_y \times A_{s,req}) / (3 \times A_{s,prov} \times \beta_b) = 163.1 \text{ N/mm}^2$

Modification for tension reinforcement

$$f_{tens} = \min(2.0, 0.55 + (477 \text{ N/mm}^2 - f_s) / (120 \times (0.9 \text{ N/mm}^2 + (M / (b_{eff} \times d^2)))) = 1.523$$

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

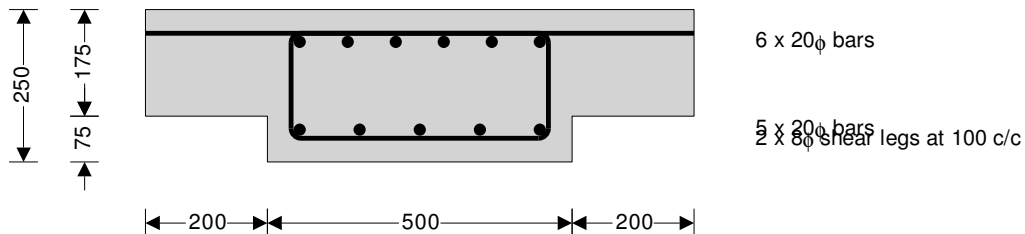
$$span\_to\_depth_{allow} = span\_to\_depth_{basic} \times f_{tens} \times f_{comp} = 33.6$$

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**

### Support B



### Rectangular section in flexure (cl.3.4.4)

Design bending moment  $M = \text{abs}(M_{B\_red}) = 122 \text{ kNm}$

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

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  $z = d \times (0.5 + (0.25 - K' / 0.9)^{0.5}) = 153 \text{ mm}$

Depth of neutral axis  $x = (d - z) / 0.45 = 98 \text{ mm}$

Depth of compression reinforcement  $d_2 = C_{nom\_b} + \phi_v + \phi_{bot} / 2 = 53 \text{ mm}$

Area of compression reinforcement required  $A_{s2,req} = (K - K') \times f_{cu} \times b \times d^2 / (0.87 \times f_y \times (d - d_2)) = 9 \text{ mm}^2$

Compression reinforcement provided  $5 \times 20\phi \text{ bars}$


Area of compression reinforcement provided  $A_{s2,prov} = 1571 \text{ mm}^2$

Maximum area of reinforcement (cl.9.2.1.1(3))  $A_{s,max} = 0.04 \times b \times h = 5000 \text{ mm}^2$

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

Area of tension reinforcement required  $A_{s,req} = K' \times f_{cu} \times b \times d^2 / (0.87 \times f_y \times z) + A_{s2,req} = 1828 \text{ mm}^2$



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beam B0.2				5.7. 6		
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ab	12/10/2016					

Tension reinforcement provided  $6 \times 20\phi$  bars  
 Area of tension reinforcement provided  $A_{s,prov} = 1885 \text{ mm}^2$   
 Minimum area of reinforcement (exp.9.1N)  $A_{s,min} = 0.0013 \times b \times h = 163 \text{ mm}^2$

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

#### Rectangular section in shear

Design shear force span 1 at 6203 mm  $V = \text{abs}(\min(V_{B_{s1\_max}}, V_{B_{s1\_red}})) = 102 \text{ kN}$   
 Design shear stress  $v = V / (b \times d) = 1.032 \text{ N/mm}^2$   
 Design concrete shear stress  $v_c = 0.79 \times \min(3, [100 \times A_{s,prov} / (b \times d)]^{1/3}) \times \max(1, (400 / d)^{1/4}) \times$   
 $(\min(f_{cu}, 40) / 25)^{1/3} / \gamma_m$

$$v_c = 1.095 \text{ N/mm}^2$$

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

**PASS - Design shear stress is less than maximum allowable**

Value of v from Table 3.7  $0.5 \times v_c < v < (v_c + 0.4 \text{ N/mm}^2)$   
 Design shear resistance required  $v_s = \max(v - v_c, 0.4 \text{ N/mm}^2) = 0.400 \text{ N/mm}^2$   
 Area of shear reinforcement required  $A_{sv,req} = v_s \times b / (0.87 \times f_{yv}) = 460 \text{ mm}^2/\text{m}$   
 Shear reinforcement provided  $2 \times 8\phi$  legs at 100 c/c  
 Area of shear reinforcement provided  $A_{sv,prov} = 1005 \text{ mm}^2/\text{m}$

**PASS - Area of shear reinforcement provided exceeds minimum required**

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

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

#### Spacing of reinforcement (cl 3.12.11)

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

#### Minimum distance between bars in tension (cl 3.12.11.1)

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

**PASS - Satisfies the minimum spacing criteria**

#### Maximum distance between bars in tension (cl 3.12.11.2)

Design service stress  $f_s = (2 \times f_y \times A_{s,req}) / (3 \times A_{s,prov} \times \beta_b) = 323.3 \text{ N/mm}^2$

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

**PASS - Satisfies the maximum spacing criteria**

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Job title: 10 Downside Crescent				
Calculations: Water uplift check		Designed: ab	Date: 11/10/2016	Ckd: -

Beam & Load description	Span mm	Area loads		Width mm	Location		UDL		Point loads	
		DL kN/m <sup>2</sup>	LL kN/m <sup>2</sup>		from mm	to mm	DL kN/m	LL kN/m	DL kN	LL kN
<u>Water uplift force</u>										
3m high water table	7000	30.00		7300					<b>1533.0</b>	
<u>Gravitational load</u>										
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									<b>1542.1</b>	<b>PASS</b>