SUBTERRANEAN IMPACT ASSESSMENT

FOR:

25 BATHURST MEWS, LONDON W2 2SB

Our Ref: 20.347

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Rev	Date	Signed
P1	17/12/20	JW

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1. INTRODUCTION

This report has been prepared for Ms Beckett and initiates the sequence of construction for the proposed basement construction at 25 Bathurst Mews, London W2 2SB.

This document is one of a series of documents that has been prepared to support the planning consent for the proposed redevelopment of the above property.

The document explores the methods incorporated to construct the proposed basement in general and the proposed sequence to be incorporated in the construction of the basement

The Contractor is to read this document in conjunction with his final method statement and therefore. The document should be used as a clear indication of how the basement is to be constructed and the final method statement should be determined by the Contractor with the Engineers approval

This report will address other issues pertaining to the development such as sequence of construction to prevent damage to adjacent properties. A borehole log will describe the soil condition on site.

Although water may not be present on the site it may be necessary during the course of the construction to dewater the site due to rising levels within the site boundary's and there effect on adjacent properties.

The report has been based on planning drawings

2 Description of Existing Property

The property is situated at 25 Bathurst Mews, London W2 2SB.
within central London and is a Terraced Mews House two stories high .

ELEVATION

PLAN

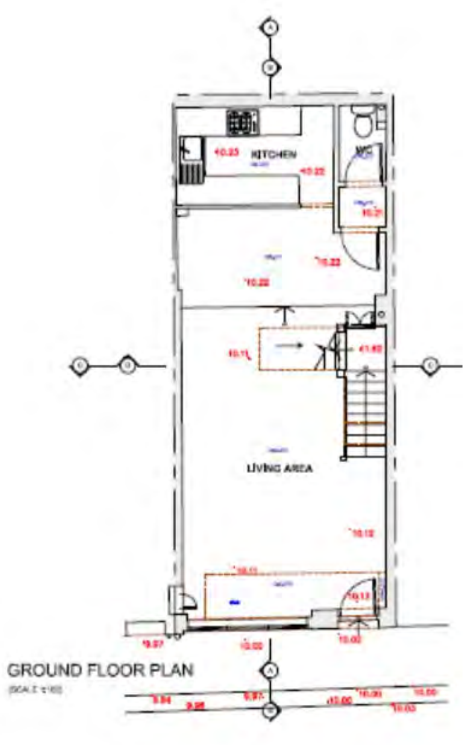
Existing property, No 25 Bathurst Mews

The property is a terraced property two stories high constructed in traditional materials brickwork walls and timber. The front elevation shows a double garage at ground floor level with a Bessemer at first floor level

We would consider the foundations to be shallow at approximately 600-700mm deep maximum, below ground level.

The property is situated off a busy access road, and the age of the building to be late Victorian or early Edwardian.

The adjacent side to (Number 26) has already had a single story basement constructed within the last 10 years.



Description of the Proposed Building

It is proposed to construct a basement over the full area of the ground floor between 24 and 26 Bathurst mews. The underpins will form part of the party wall.

The basement will be constructed with a perimeter underpin of not more than 1m length pins to the proposed level of the basement at 2.9m-3.0m below existing ground level.

4 Issues to address in arriving at the strategy for the sequence of construction.

Existing structure to both properties is to remain and the basement works are to commence from the inside of the building (25 Bathurst mews)

Service utilities are to be disconnected at or beyond the site boundary

The basement covers a large proportion of the site and the onsite workers environment will not be compromised, as the basement is being constructed in an underpinning sequence. The first floor can be utilized, until late in the construction as a welfare area or alternatively the floor is to remain, and is supported on steel beams with intermediate lintels to support the ground slab .

A hoarding will be required to allow for the excavation of the soil/clay to the front of the property, this will be minimal, and calculations should consider the design of any surcharge from the adjacent properties on the party walls this is generally where a 10kPa surcharge is applied.

Adjacent dwellings -

No 24 Bathhurst mews

The adjacent properties are similar in style and age. The party walls are to be underpinned, a Party Wall award being required on both sides of the properties.

The wall adjacent No 26 has been underpinned, to form a new basement We would therefore consider the effects on the adjacent property (No 25) to be nominal, as the wall has been underpinned in a sequence and we have assumed with good workmanship, essential to preventing any settlement on the party walls.

The bearing capacity for the existing foundations of No 24, could be dissimilar to that of the proposed, with little affect on the adjacent properties. There will be a slight difference on bearing capacity as the strata below will have a greater bearing capacity due to the overburden load from the existing soils.

The above can be determined by a GMA (Ground Movement Assessment) and will give theoretical levels of movement vertically and horizontally in accordance with the BRE recommendations, normally within the first two levels of 0 and 1 (slight damage) which can be controlled with redecoration, if required.

Heave has been considered, and the affect on the walls due to the loading of the adjacent properties, to be negligible for a single story property. We would consider short term and long term heave in the region of 15mm total, with the short term heave from the clay, being in the region of 8-9mm (Refer to Geology). Heave has been considered in the design, as well as flotation from any hydrostatic pressure due to water leaks or unforeseen rise in the water table (water table at approx. 2.5m).

Public roads and footpaths

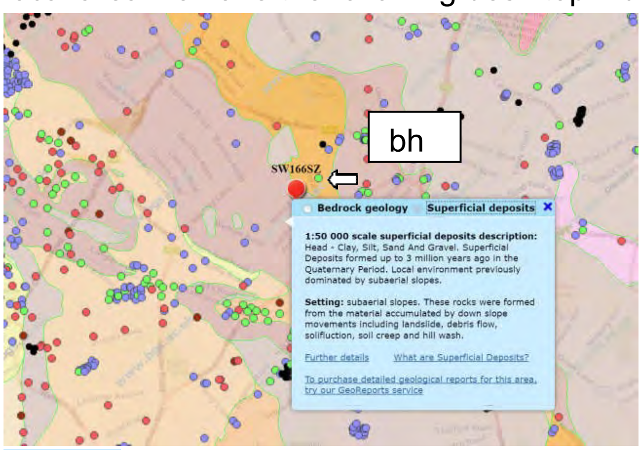
There are public footpaths adjacent to the entrance of No 25 Bathurst mews

We do not envisage heavy traffic during the construction, however, heavy traffic for removing of materials will occur, and if deemed necessary steel spreader plates over the entrance, are to be allowed for during the construction of the new basement.

Services in the adjacent footpath and road ways will need to be surveyed and protected from site traffic as mentioned in the previous paragraphs.

Ground conditions

A soils investigation has not been instigated to date due to occupancy of the property; however, from a desk top survey and knowledge of the local area we have the following desk top indication of the soils.



superficial

1:50 000 scale superficial deposits description:
Head - Clay, Silt, Sand and Gravel. Superficial Deposits formed up to 3 million years ago in the Quaternary Period. Local environment previously dominated by subaerial slopes.

Bedrock

1:50 000 scale bedrock geology description: London Clay Formation - Clay, Silt And Sand. Sedimentary Bedrock formed approximately 34 to 5 million years ago in the Palaeogene Period. Local environment previously dominated by deep seas.

We have obtained a borehole log of the local geology which would indicate initial sand and gravels and then London clay at a lower level. This would correspond to the geological maps of the area.

Water Table

No water was found within the aforementioned borehole log. This may not be the case within Bathurst Mews, as previous records have noted water at approximately 2.0-3.0m, and some water must be considered during the construction of the basement.

Heave

Clay has been found at 2-2.5m below existing ground level of the proposed excavation level, and some heave will occur from previous calculations pertaining to ground heave at 3.5m the maximum would be in the region of 10mm-15mm long and short term

If we consider 50% of short term heave taking place during construction, the remaining uplift loading can be considered in the design of the basement slab.

The slab should therefore be adequately stiff to withstand the loading from both a raised water table, in accordance with BS 8102 or the residual heave from the clay.

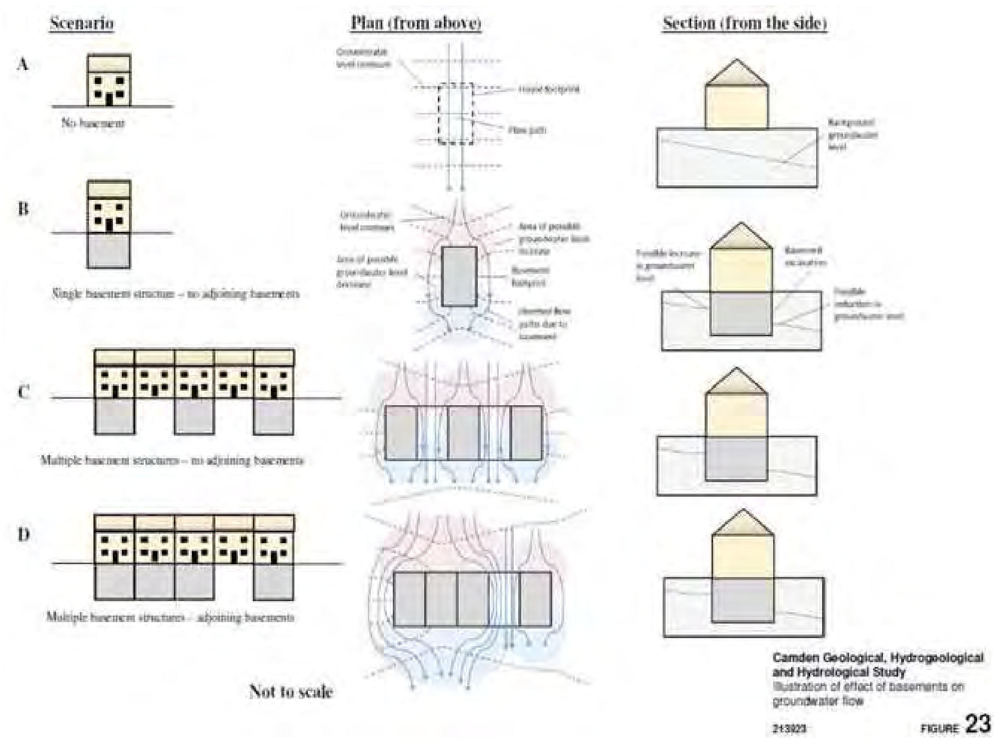
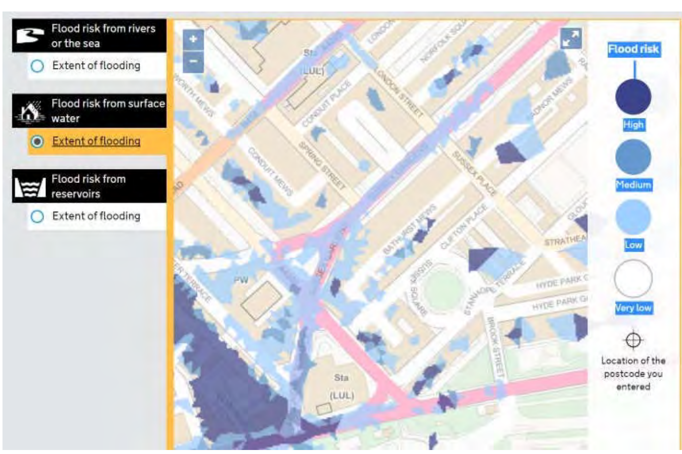


Figure 11 Extract From Arup report on ground water flow

Ground flow between basements



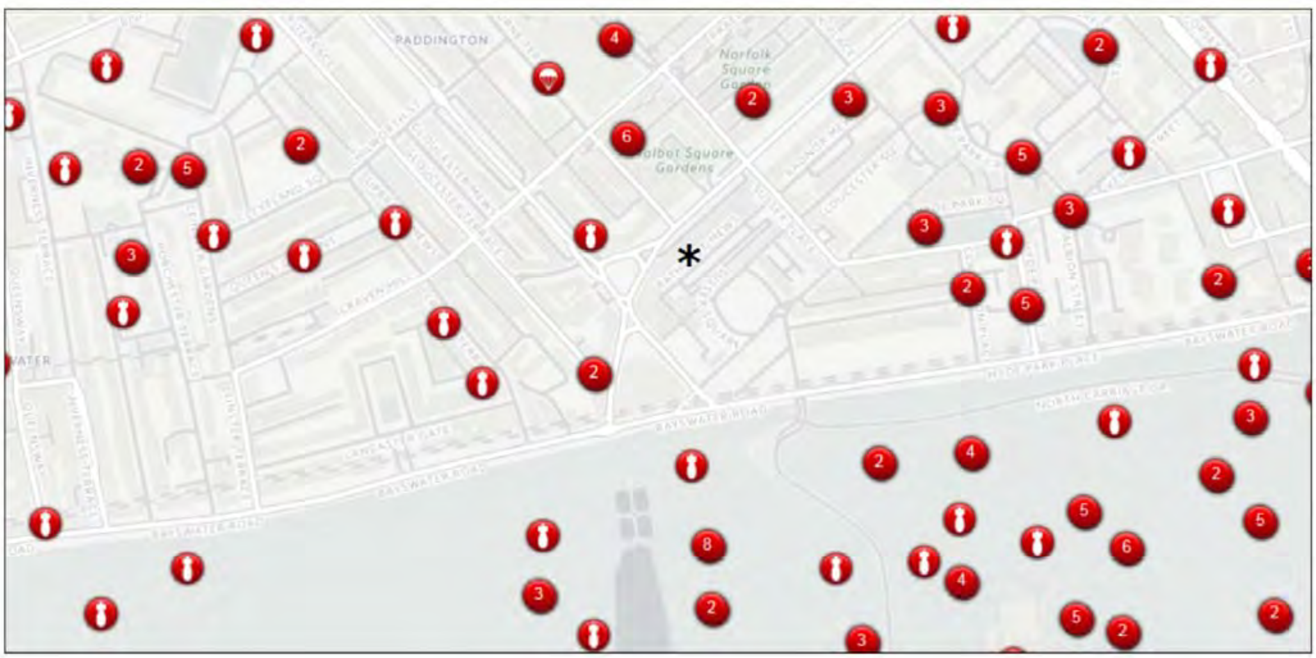
Flood Risk from Surface Water

It can be seen some areas of Bathurst mews are at risk from surface water flooding, adequate protection such as an acco drain to be installed at the entrance to the property, or similar arrangements to prevent flooding of the basement.

Flood Risk from Rivers and Seas

The environment agency indicates no risk from flooding from the rivers

Potential bomb damage



* Site location

Figure (j) - WWII Bomb Record Map
(Extract from bombsight.org)

DRAINAGE STRATAGEY

It is intended to use the existing foul and storm water to ground floor level the basement is to have a foul and storm water pump to the new manhole external of the building within Bathgate mews (to be agreed with Thames water).
All drains to have 1:60 fall or confirmed with Thames water

Sequence of Construction

General

1. This project is to create an additional basement to 25 Bathurst Mews , it is intended to underpin the existing foundations to the building to a level of approximately 2.5m finished floor to ceiling.
2. The existing ground floor is assumed to be constructed with timber floor joists to the front and rear of the property
3. Existing loadbearing walls are to be supported by means of needling or props, directly below the wall as the excavations proceed into the building the walls are to be assessed and propped accordingly to the correct loading
4. Excavation will be completed with hand tools powered by compressed air and by a mini – digger, if and where appropriate.
5. A conveyor belt will be installed at the front of the property. A local excavation will be excavated from the existing ground floor down to the new basement level. The conveyor will then be installed up to the street level. The conveyor will extend out to the position of the skip. A temporary hoarding will be installed to secure the conveyor belt. The exact position of the conveyor will be confirmed when works commence on site. Spoil will be wheel barrowed from the face of the excavation to the base of the conveyor belt.
6. Spoil will be removed via the conveyor belt and deposited into a skip placed on the road directly in front of the property. The skip will be exchanged when it is full, or alternately a grab lorry will be used to remove the spoil from the skip.

Underpinning – General

7. Underpinning bases will be excavated in short sections not exceeding 1000mm in width, in the 1 to 5 underpinning sequence. Each section will be constructed with its base to allow for stability during the construction.
8. When the existing foundation to the party wall is exposed, any stepped brick footings protruding into our site will be carefully trimmed back using hand tools to avoid causing any damage to the foundation. The stepped brick footings will be trimmed back to be flush in-line with the party wall above.
9. The sequence of the underpinning will be such that no more than 20% of any section of the party wall will be undermined, at any one time. Underpins will be sequenced such that any given underpin will be completed, dry packed, and a minimum period of 24 hours lapsed before an adjacent excavation commenced to form another underpin. The exact sequence will be developed by the engineer, when the existing ground conditions, and the quality of the existing foundations become known as works progress. All underpins will be constructed in accordance with the underpinning specification.
10. In the event that the existing foundations to the party wall are found to be unstable, sacrificial steel jacks will be installed underneath the foundation to prop the bottom few courses of bricks. These steel jacks will be left in place and will be incorporated into the concrete stem.
11. In the event that the ground is unstable, lateral propping will be provided as required to the rear and sides of the excavation using trench sheeting or plywood, timber and Acrow props as appropriate. Should the rear face of the excavation (i.e. underneath the party wall) require support, sacrificial back – shutters will be used (Refer to method statement for underpinning).

12. Concrete will be chuted into a ‘bath’ within the excavated basement and placed by wheelbarrow and / or bucket. The exact arrangement

will be finalised when works commence on site.

13. Excavation for an underpin section will be dug in a day, and the concrete to the base poured by the end of the same day.
14. The concrete to the stem of the underpin will be poured the following day. This will be poured up to within 50 – 75mm of the underside of the existing party wall foundations.
15. On the following day, the gap between the concrete and the underside of the existing foundation will be drypacked with a mixture of sharp sand and cement (ratio 1:3), rammed tight.
16. A day will be allowed before adjacent sections will be excavated to form a new underpin.

Party Walls to 24/26 Bathurst mews London W2

17. Back prop wall with acrow props at 1500mm centres onto concrete sleepers, screw props into the existing wall. Where it is found that the wall is not capable of receiving the props The Contractor is to report to the engineer for further instructions, and an alternative method sort or possibly rebuild to be confirmed on site.
18. Cast mass concrete base in accordance with the engineers drawings and sequence of operations, allow for 24 hours prior to casting retaining wall, allow for 4No M16 dowels to each unreinforced Mass Concrete base as a shear key or toggle joint the base at third points.
19. Check levels and positions of footings and underpin in accordance with The engineers drawings
20. Cast reinforced retaining wall allow to cure for 24 hours, dry pack in a 1:3 mortar and allow to cure for a further 24 hours.
21. When the backfill to a section of underpinning is completed, the next underpinning section will be excavated, in the 1 to 5 sequence.
22. The underpinning will be carried out in this manner until all the reinforced concrete underpinning to the party walls is completed. Allowing for the sump position.

23. When the underpinning is completed remove the nibs from the existing brickwork.
24. Install all drainage associated with cavity drain and sump.
25. Cast remaining slab, laid to falls to drainage points within the slab to the proposed Waterproofing specialist details , and foundations in accordance with The engineers details

General underpin to adjacent properties

26. Check levels and positions of footings and underpin in accordance with drawings
27. Cast reinforced retaining wall allow to cure for 24 hours, dry pack in a 1:3 mortar and allow to cure for a further 24 hours.
28. When the backfill to a section of underpinning is completed, the next underpinning section will be excavated, in the 1 to 5 sequence.
29. The underpinning will be carried out in this manner until all the reinforced concrete underpinning to the party walls is completed. Allowing for the sump position.
30. When the underpinning is completed remove the nibs from the existing brickwork.
31. Install all drainage associated with cavity drain and sump laid to falls if required , and foundations in accordance with drawings

Installation ground floor slab

32. Install pad stones in accordance with drawings
33. Install steels to ground floor in accordance with drawings and remove props from existing walls supporting the first floor
34. Install Timber floor into the steels in accordance with the

manufacturers instructions onto beams and channel sections indicated on drawing or concrete floor to suit client

35. Place metal deck and cast insitu slab in accordance with the manufacturer's instructions finish to be as Architects required details to receive waterproofing details
36. Dry pack supporting walls onto steel beams with 1:3 mortar pack

Post – Structural Works

37. On completion of all structural works, a drained cavity layer will be laid on top of the new internal basement slab and lined to the retaining wall faces as indicated on the specialists drawings
38. A layer of insulation will be placed on top of the drained cavity layer to the basement slab.
39. A fibre mesh reinforced screed will be laid on top of the insulation to form the finished basement floor.
40. Metal studwork is to be constructed to the internal faces of the walls to the Architects details and recommendations.

Appendix A
Borehole logs (Local Area approx. 100m away)

British Geological Survey	Site: CrossRail Package A - CR/D/206	Borehole Number: RT9

Boring Method	Casing Diameter	Ground Level (mOD)	Client	Job Number
Cable Percussion		124.20		M2019/3
	Location	Dates: 14/04/1992	Engineer: Exploration Associates	Sheet: 1/3

Depth (m)	Sample / Tests	Casing Depth (m)	Water Depth (m)	Field Records	Level (mOD)	Depth (m) (Thickness)	Description	Legend	Water
						(0.40)	MADE GROUND: tarmac over concrete ** [Made Ground]		
0.40-1.50	B1				123.80	0.40	MADE GROUND: Broken concrete fill. [Made Ground]		
						(1.10)			
1.50-2.00	B1				122.70	1.50	MADE OR DISTURBED GROUND: Soft orange brown sandy clay with some fine and medium subangular and subrounded flint gravel and brick fragments. [Made Ground]		
2.00-2.45 2.00-2.45	SPT N=6 D1			1,1/1,1,2,2		(1.00)			
2.50-3.20	B1				121.70	2.50 (0.70)	Soft dark brown sandy CLAY with some fine and medium flint gravel. [?Alluvium?]		
3.20-3.65 3.20-3.65	CPT N=15 C1			2,3/3,3,4,5	121.00	3.20	Medium dense light to mid orange brown clayey to very clayey SAND with a little to some fine to coarse subangular to subrounded flint gravel with some sandy clay layers. [Terrace Gravels]		
3.70-4.30	B1						Below 3.70m - with occasional cobbles tending to claybound gravel		
4.30-4.75 4.30-4.75	CPT N=18 C1			2,3/3,5,5,5		(2.30)			
4.80-5.20	B1								
5.20-5.65 5.20-5.65	CPT N=13 C1			1,2/2,4,3,4					
					118.70	5.50	Soft/firm brown CLAY ** [Disturbed London Clay]		
5.70-6.15	U1			20 blows		(0.50)			
					118.20	6.00	Firm unstructured to indistinctly laminated extremely to very closely fissured mid to dark grey brown silty CLAY. Trace of mica and sand. Rare light grey silt filaments and partings. Fissures generally CP/P Sm Cl. Occasionally clay smeared. [London Clay]		
6.15 6.25-6.70 6.25-6.70	D1 SPT N=13 D1			2,2/2,3,4,4					
7.00	D1						Below 7.00m - rare pockets <5mm of black fine sandy silt		
7.20-7.65	U1			20 blows		(2.50)			
7.65	D1						At 7.75m - with rare shell fragments		
8.50	D1				115.70	8.50	Stiff unstructured to indistinctly laminated extremely to very closely fissured mid to dark grey brown silty CLAY. Trace of mica and sand. Rare light grey silt filaments. Rare pockets and partings of light grey brown and of black fine sandy silt. Fissures CP/P Sm Cl. [London Clay]		
8.70-9.15	U1			20 blows					
9.15 9.20-9.65	D1 U1			22 blows					
9.70-10.15	U1			26 blows					

Remarks
1. Inspection pit dug (1.50m x 1.00m x 1.80m deep) 3.5 hrs.~NOTE: Previous pit dug in Sussex Gardens and abandoned - 9 hrs. 2. Pneumatic piezometer installed on 15/04/92, tip at 20.00m Grout to 21.50m, seal to 20.50m, sand to 19.30m, seal to 18.50m, grout to 0.50m with stop cock box cover concreted at surface.

Scale (approx)	Logged By
1:50	CL
Figure No.	

#

Appendix B
Construction sketches & Calculations

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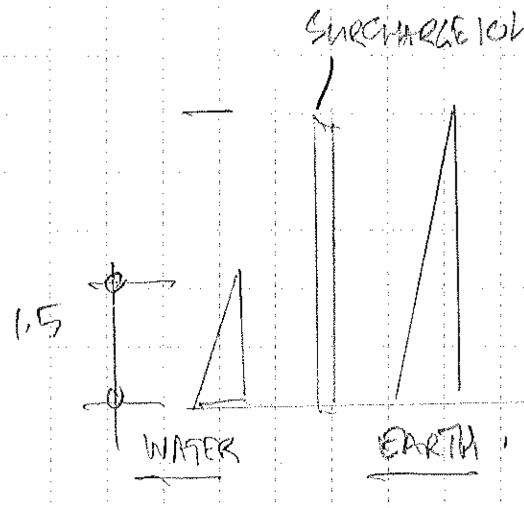
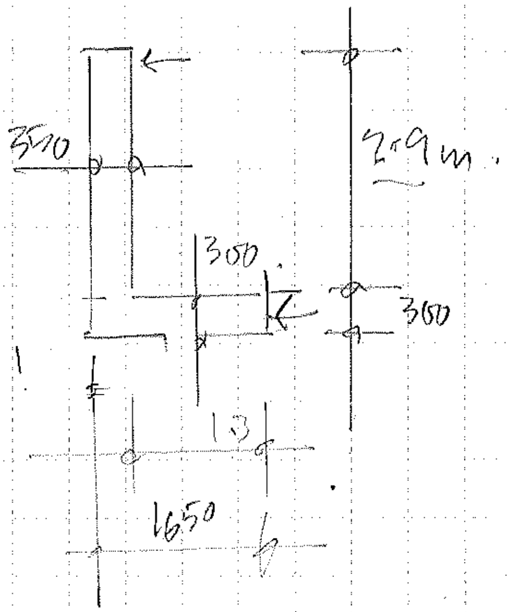
DESIGN OF PROPOSED RETAINING WALLS (2.9m)

LOADING.

WALL (A).

			DL	LL
ROOF	– 4.3/2 × 2.1 × 2.0	= 9.0 KN/m²	4.8	4.1
1ST	2.5 × 4.3/2 × 2.0	= 10.8	1.1	8.6
GRD.	6.8 × 4.3/2 × 2.0	= 29.2	17.4	12.0
WALL	5.2 × 6.0	= 33.8	31.2	
			54.0	24.7



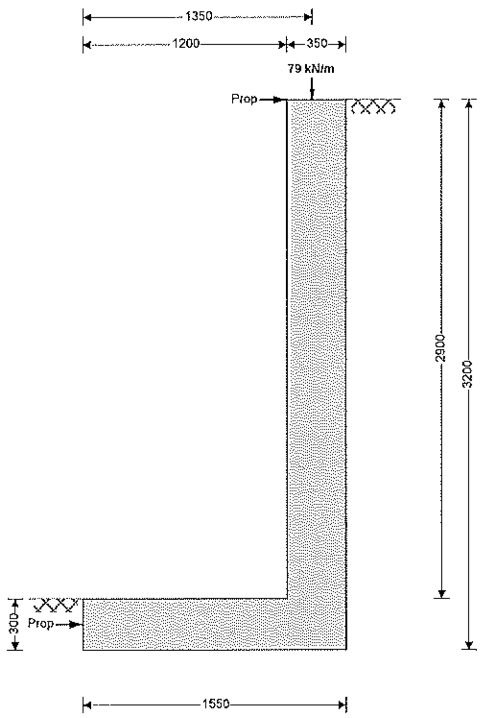


COMBINATIONS ① DL + LL + EARTH.
② DL + EARTH + SUR + WATER.

RETAINING WALL ANALYSIS & DESIGN (BS8002)

RETAINING WALL ANALYSIS (BS 8002:1994)

TEDDS calculation version 1.2.01.06



Wall details

Retaining wall type	**Cantilever propped at both**
Height of retaining wall stem	h_{stem} = **2900** mm
Thickness of wall stem	t_{wall} = **350** mm
Length of toe	l_{toe} = **1200** mm
Length of heel	l_{heel} = **0** mm
Overall length of base	$l_{base} = l_{toe} + l_{heel} + t_{wall}$ = **1550** mm
Thickness of base	t_{base} = **300** mm
Depth of downstand	d_{ds} = **0** mm
Position of downstand	l_{ds} = **1200** mm
Thickness of downstand	t_{ds} = **300** mm
Height of retaining wall	$h_{wall} = h_{stem} + t_{base} + d_{ds}$ = **3200** mm
Depth of cover in front of wall	d_{cover} = **0** mm
Depth of unplanned excavation	d_{exc} = **0** mm
Height of ground water behind wall	h_{water} = **0** mm
Height of saturated fill above base	$h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0\text{ mm})$ = **0** mm
Density of wall construction	γ_{wall} = **23.6** kN/m^3
Density of base construction	γ_{base} = **23.6** kN/m^3
Angle of rear face of wall	α = **90.0** deg
Angle of soil surface behind wall	β = **0.0** deg
Effective height at virtual back of wall	$h_{eff} = h_{wall} + l_{heel} \times \tan(\beta)$ = **3200** mm

Retained material details

Mobilisation factor	M = **1.5**

Moist density of retained material γ_m = **16.0** kN/m^3

Saturated density of retained material γ_s = **20.0** kN/m^3

Design shear strength ϕ' = **24.2** deg

Angle of wall friction δ = **18.6** deg

Base material details

Firm clay

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

Design shear strength ϕ'_b = **24.2** deg

Design base friction δ_b = **18.6** deg

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

Using Coulomb theory

Active pressure coefficient for retained material

$$K_a = \sin(\alpha + \phi')^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta) \times [1 + \sqrt{(\sin(\phi' + \delta) \times \sin(\phi' - \beta) / (\sin(\alpha - \delta) \times \sin(\alpha + \beta)))}]^2) = \mathbf{0.369}$$

Passive pressure coefficient for base material

$$K_p = \sin(90 - \phi'_b)^2 / (\sin(90 - \delta_b) \times [1 - \sqrt{(\sin(\phi'_b + \delta_b) \times \sin(\phi'_b) / (\sin(90 + \delta_b)))}]^2) = \mathbf{4.187}$$

At-rest pressure

At-rest pressure for retained material $K_0 = 1 - \sin(\phi')$ = **0.590**

Loading details

Surcharge load on plan Surcharge = **0.0** kN/m^2

Applied vertical dead load on wall W_{dead} = **54.0** kN/m

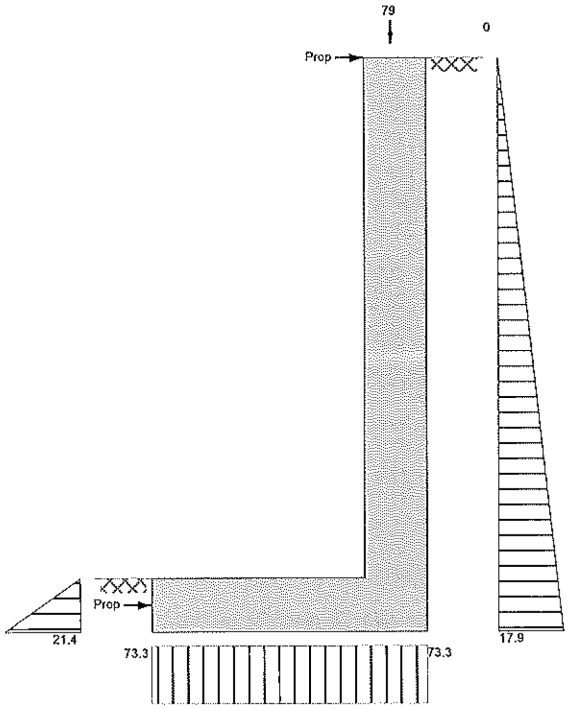
Applied vertical live load on wall W_{live} = **24.7** kN/m

Position of applied vertical load on wall l_{load} = **1350** mm

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

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

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



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

Vertical forces on wall

Wall stem — $w_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall}$ = **24** kN/m

Wall base — $w_{base} = l_{base} \times t_{base} \times \gamma_{base}$ = **11** kN/m

Applied vertical load — $W_v = W_{dead} + W_{live}$ = **78.7** kN/m

Total vertical load — $W_{total} = w_{wall} + w_{base} + W_v$ = **113.6** kN/m

Horizontal forces on wall

Moist backfill above water table — $F_{m\_a} = 0.5 \times K_a \times \cos(90 - \alpha + \delta) \times \gamma_m \times (h_{eff} - h_{water})^2$ = **28.7** kN/m

Total horizontal load — $F_{total} = F_{m\_a}$ = **28.7** kN/m

Calculate total propping force

Passive resistance of soil in front of wall — $F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **3.2** kN/m

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

F_{prop} = **0.0** kN/m

Overturning moments

Moist backfill above water table — $M_{m\_a} = F_{m\_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **30.6** kNm/m

Total overturning moment — $M_{ot} = M_{m\_a}$ = **30.6** kNm/m

Restoring moments

Wall stem — $M_{wall} = w_{wall} \times (l_{toe} + t_{wall} / 2)$ = **32.9** kNm/m

Wall base — $M_{base} = w_{base} \times l_{base} / 2$ = **8.5** kNm/m

Design vertical dead load — $M_{dead} = W_{dead} \times l_{load}$ = **72.9** kNm/m

Total restoring moment — $M_{rest} = M_{well} + M_{base} + M_{dead}$ = **114.3** kNm/m

Check bearing pressure

Total vertical reaction — $R = W_{total}$ = **113.6** kN/m

Distance to reaction — $x_{bar} = l_{bese} / 2$ = **775** mm

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

Reaction acts within middle third of base

Bearing pressure at toe — $p_{toe} = (R / l_{base}) - (6 \times R \times e / l_{base}^2)$ = **73.3** kN/m²

Bearing pressure at heel — $p_{heel} = (R / l_{base}) + (6 \times R \times e / l_{base}^2)$ = **73.3** kN/m²

PASS - Maximum bearing pressure is less than allowable bearing pressure

Calculate propping forces to top and base of wall

Propping force to top of wall

$F_{prop\_top} = (M_{ot} - M_{rest} + R \times l_{base} / 2 - F_{prop} \times t_{base} / 2) / (h_{stem} + t_{base} / 2)$ = **1.407** kN/m

Propping force to base of wall — $F_{prop\_base} = F_{prop} - F_{prop\_top}$ = **-1.407** kN/m

RETAINING WALL DESIGN (BS 8002:1994)

TEDDS calculation version 1.2.01.06

Ultimate limit state load factors

Dead load factor γ_{f_d} = **1.4**

Live load factor γ_{f_l} = **1.6**

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

Factored vertical forces on wall

Wall stem $w_{wall\_f} = \gamma_{f\_d} \times h_{stem} \times t_{wall} \times \gamma_{wall}$ = **33.5** kN/m

Wall base $w_{base\_f} = \gamma_{f\_d} \times l_{base} \times t_{base} \times \gamma_{base}$ = **15.4** kN/m

Applied vertical load $W_{v\_f} = \gamma_{f\_d} \times W_{dead} + \gamma_{f\_l} \times W_{live}$ = **115.1** kN/m

Total vertical load $W_{total\_f} = w_{wall\_f} + w_{base\_f} + W_{v\_f}$ = **164** kN/m

Factored horizontal at-rest forces on wall

Moist backfill above water table $F_{m\_a\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2$ = **67.7** kN/m

Total horizontal load $F_{total\_f} = F_{m\_a\_f}$ = **67.7** kN/m

Calculate total propping force

Passive resistance of soil in front of wall $F_{p\_f} = \gamma_{f\_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **4.5** kN/m

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

F_{prop_f} = **21.3** kN/m

Factored overturning moments

Moist backfill above water table $M_{m\_a\_f} = F_{m\_a\_f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **72.2** kNm/m

Total overturning moment $M_{ot\_f} = M_{m\_a\_f}$ = **72.2** kNm/m

Restoring moments

Wall stem $M_{wall\_f} = w_{wall\_f} \times (l_{toe} + t_{wall} / 2)$ = **46.1** kNm/m

Wall base $M_{base\_f} = w_{base\_f} \times l_{base} / 2$ = **11.9** kNm/m

Design vertical load $M_{v\_f} = W_{v\_f} \times l_{load}$ = **155.4** kNm/m

Total restoring moment $M_{rest\_f} = M_{wall\_f} + M_{base\_f} + M_{v\_f}$ = **213.4** kNm/m

Factored bearing pressure

Total vertical reaction $R_f = W_{total\_f}$ = **164.0** kN/m

Distance to reaction $x_{bar\_f} = l_{base} / 2$ = **775** 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 $p_{toe\_f} = (R_f / l_{base}) - (6 \times R_f \times e_f / l_{base}^2)$ = **105.8** kN/m²

Bearing pressure at heel $p_{heel\_f} = (R_f / l_{base}) + (6 \times R_f \times e_f / l_{base}^2)$ = **105.8** kN/m²

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

Bearing pressure at stem / toe $p_{stem\_toe\_f} = \max(p_{toe\_f} - (\text{rate} \times l_{toe}), 0 \text{ kN/m}^2)$ = **105.8** kN/m²

Bearing pressure at mid stem $p_{stem\_mid\_f} = \max(p_{toe\_f} - (\text{rate} \times (l_{toe} + t_{wall} / 2)), 0 \text{ kN/m}^2)$ = **105.8** kN/m²

Bearing pressure at stem / heel $p_{stem\_heel\_f} = \max(p_{toe\_f} - (\text{rate} \times (l_{toe} + t_{wall})), 0 \text{ kN/m}^2)$ = **105.8** kN/m²

Calculate propping forces to top and base of wall

Propping force to top of wall

$F_{prop\_top\_f} = (M_{ot\_f} - M_{rest\_f} + R_f \times l_{base} / 2 - F_{prop\_f} \times t_{base} / 2) / (h_{stem} + t_{base} / 2)$ = **-5.679** kN/m

Propping force to base of wall $F_{prop\_base\_f} = F_{prop\_f} - F_{prop\_top\_f}$ = **26.955** kN/m

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

Material properties

Characteristic strength of concrete f_{cu} = **35** N/mm^2

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

Base details

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

Cover to reinforcement in toe c_{toe} = **50** mm

Calculate shear for toe design

Shear from bearing pressure $V_{toe\_bear} = (p_{toe\_f} + p_{stem\_toe\_f}) \times l_{toe} / 2$ = **127** kN/m

Shear from weight of base $V_{toe\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{toe} \times t_{base}$ = **11.9** kN/m

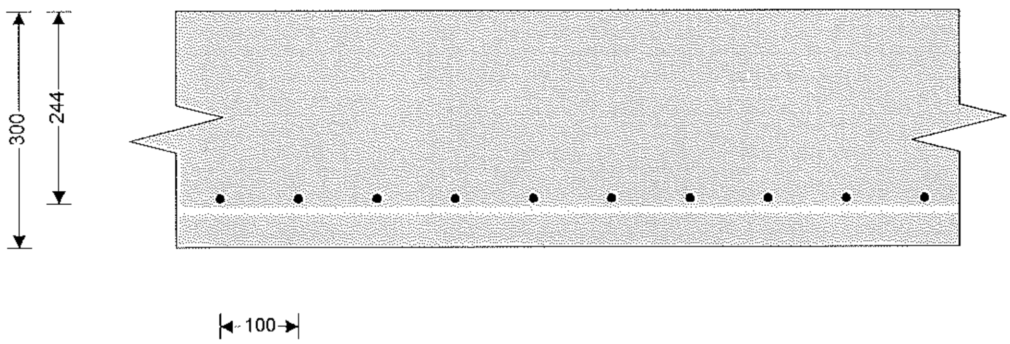
Total shear for toe design $V_{toe} = V_{toe\_bear} - V_{toe\_wt\_base}$ = **115.1** kN/m

Calculate moment for toe design

Moment from bearing pressure $M_{toe\_bear} = (2 \times p_{toe\_f} + p_{stem\_mid\_f}) \times (l_{toe} + t_{wall} / 2)^2 / 6$ = **100** kNm/m

Moment from weight of base $M_{toe\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2 / 2)$ = **9.4** kNm/m

Total moment for toe design $M_{toe} = M_{toe\_bear} - M_{toe\_wt\_base}$ = **90.7** kNm/m



Check toe in bending

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

Depth of reinforcement $d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2)$ = **244.0** mm

Constant $K_{toe} = M_{toe} / (b \times d_{toe}^2 \times f_{cu})$ = **0.044**

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} = **232** mm

Area of tension reinforcement required $A_{s\_toe\_des} = M_{toe} / (0.87 \times f_y \times z_{toe})$ = **900** mm^2/m

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

Area of tension reinforcement required $A_{s\_toe\_req} = \max(A_{s\_toe\_des}, A_{s\_toe\_min})$ = **900** mm^2/m

Reinforcement provided **12 mm dia.bars @ 100 mm centres**

Area of reinforcement provided $A_{s\_toe\_prov}$ = **1131** mm^2/m

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress $v_{toe} = V_{toe} / (b \times d_{toe})$ = **0.472** N/mm^2

Allowable shear stress $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1 \text{ N/mm}^2)}, 5) \times 1 \text{ N/mm}^2$ = **4.733** 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} = **0.619** N/mm^2

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

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

Material properties

Characteristic strength of concrete — f_{cu} = **35** N/mm^2

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

Wall details

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

Cover to reinforcement in stem — c_{stem} = **50** mm

Cover to reinforcement in wall — c_{wall} = **50** mm

Factored horizontal at-rest forces on stem

Moist backfill above water table — $F_{s\_m\_a\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2$ = **55.6** kN/m

Calculate shear for stem design

Moist backfill above water table — $V_{s\_m\_a\_f} = F_{s\_m\_a\_f} \times b_l \times ((5 \times L^2) - b_l^2) / (5 \times L^3)$ = **43.3** kN/m

Total shear for stem design — $V_{stem} = V_{s\_m\_a\_f}$ = **43.3** kN/m

Calculate moment for stem design

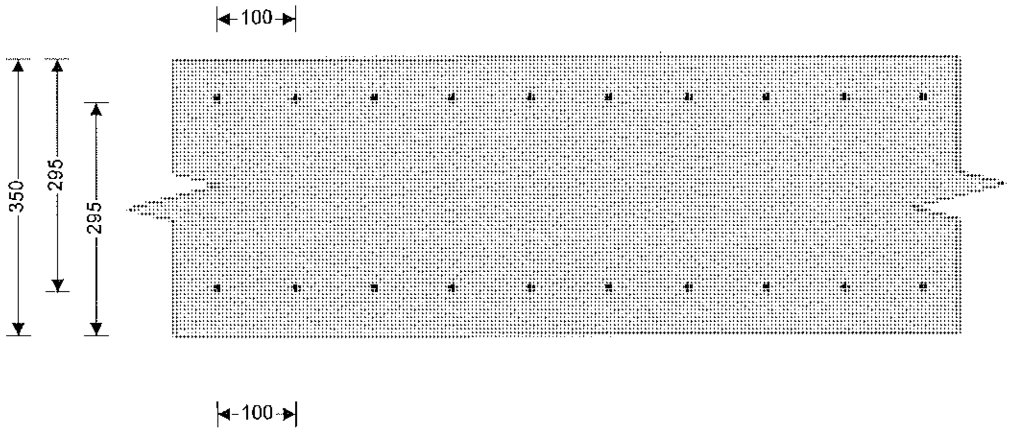
Moist backfill above water table — $M_{s\_m\_a} = F_{s\_m\_a\_f} \times b_l \times ((5 \times L^2) - (3 \times b_l^2)) / (15 \times L^2)$ = **24.6** kNm/m

Total moment for stem design — $M_{stem} = M_{s\_m\_a}$ = **24.6** kNm/m

Calculate moment for wall design

Moist backfill above water table — $M_{w\_m\_a} = F_{s\_m\_a\_f} \times 0.577 \times b_l \times [(b_l^3 + 5 \times a_l \times L^2)/(5 \times L^3) - 0.577^2/3]$ = **10.2** kNm/m

Total moment for wall design — $M_{wall} = M_{w\_m\_a}$ = **10.2** kNm/m



Check wall stem in bending

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

Depth of reinforcement — $d_{stem} = t_{wall} - c_{stem} - (\phi_{stem} / 2)$ = **295.0** mm

Constant — $K_{stem} = M_{stem} / (b \times d_{stem}^2 \times f_{cu})$ = **0.008**

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} = **280** mm

Area of tension reinforcement required — $A_{s\_stem\_des} = M_{stem} / (0.87 \times f_y \times z_{stem})$ = **202** mm^2/m

Minimum area of tension reinforcement — $A_{s\_stem\_min} = k \times b \times t_{wall}$ = **455** mm^2/m

Area of tension reinforcement required — $A_{s\_stem\_req} = \mathrm{Max}(A_{s\_stem\_des}, A_{s\_stem\_min})$ = **455** mm^2/m

Reinforcement provided — **B785 mesh**

Area of reinforcement provided — $A_{s\_stem\_prov}$ = **785** mm^2/m

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress — $v_{stem} = V_{stem} / (b \times d_{stem})$ = **0.147** N/mm^2

Allowable shear stress — $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1 \text{ N/mm}^2)}, 5) \times 1 \text{ N/mm}^2$ = **4.733** 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} = **0.491** N/mm^2

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

Check mid height of wall in bending

Depth of reinforcement — $d_{wall} = t_{wall} - c_{wall} - (\phi_{wall} / 2)$ = **295.0** mm

Constant — $K_{wall} = M_{wall} / (b \times d_{wall}^2 \times f_{cu})$ = **0.003**

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} = **280** mm

Area of tension reinforcement required — $A_{s\_wall\_des} = M_{wall} / (0.87 \times f_y \times z_{wall})$ = **84** mm^2/m

Minimum area of tension reinforcement — $A_{s\_wall\_min} = k \times b \times t_{wall}$ = **455** mm^2/m

Area of tension reinforcement required — $A_{s\_wall\_req} = \text{Max}(A_{s\_wall\_des}, A_{s\_wall\_min})$ = **455** mm^2/m

Reinforcement provided — **B785 mesh**

Area of reinforcement provided — $A_{s\_wall\_prov}$ = **785** mm^2/m

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

Check retaining wall deflection

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

Design service stress — $f_s = 2 \times f_y \times A_{s\_stem\_req} / (3 \times A_{s\_stem\_prov})$ = **193.1** N/mm^2

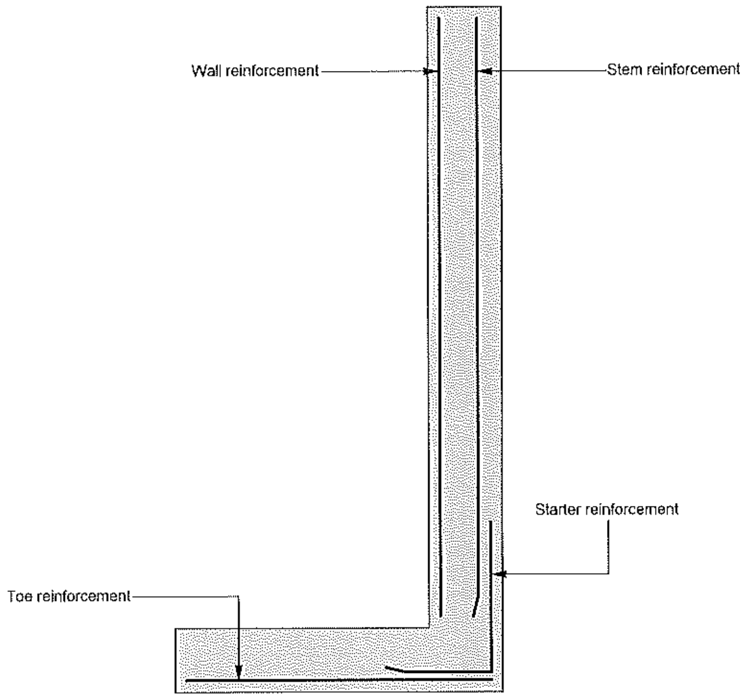
Modification factor — $factor_{tens} = \min(0.55 + (477 \text{ N/mm}^2 - f_s)/(120 \times (0.9 \text{ N/mm}^2 + (M_{stem}/(b \times d_{stem}^2)))), 2)$ = **2.00**

Maximum span/effective depth ratio — $ratio_{max} = ratio_{bas} \times factor_{tens}$ = **40.00**

Actual span/effective depth ratio — $ratio_{act} = h_{stem} / d_{stem}$ = **9.83**

PASS - Span to depth ratio is acceptable

Indicative retaining wall reinforcement diagram

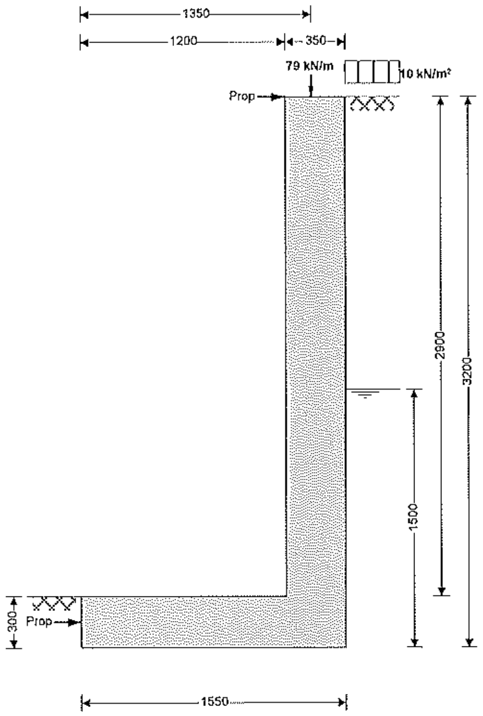


Toe bars - 12 mm dia.@ 100 mm centres - (1131 mm^2/m)
Wall mesh - B785 - (785 mm^2/m)
Stem mesh - B785 - (785 mm^2/m)

RETAINING WALL ANALYSIS & DESIGN (BS8002) (2)

RETAINING WALL ANALYSIS (BS 8002:1994)

TEDDS calculation version 1.2.01.06



Wall details

Retaining wall type	**Cantilever propped at both**
Height of retaining wall stem	h_{stem} = **2900** mm
Thickness of wall stem	t_{wall} = **350** mm
Length of toe	l_{toe} = **1200** mm
Length of heel	l_{heel} = **0** mm
Overall length of base	$l_{base} = l_{toe} + l_{heel} + t_{wall}$ = **1550** mm
Thickness of base	t_{base} = **300** mm
Depth of downstand	d_{ds} = **0** mm
Position of downstand	l_{ds} = **1200** mm
Thickness of downstand	t_{ds} = **300** mm
Height of retaining wall	$h_{wall} = h_{stem} + t_{base} + d_{ds}$ = **3200** mm
Depth of cover in front of wall	d_{cover} = **0** mm
Depth of unplanned excavation	d_{exc} = **0** mm
Height of ground water behind wall	h_{water} = **1500** mm
Height of saturated fill above base	$h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0\text{ mm})$ = **1200** mm
Density of wall construction	γ_{wall} = **23.6** kN/m^3
Density of base construction	γ_{base} = **23.6** kN/m^3
Angle of rear face of wall	α = **90.0** deg
Angle of soil surface behind wall	β = **0.0** deg
Effective height at virtual back of wall	$h_{eff} = h_{wall} + l_{heel} \times \tan(\beta)$ = **3200** mm

Retained material details

Mobilisation factor	M = **1.5**

Moist density of retained material γ_m = **16.0** kN/m^3

Saturated density of retained material γ_s = **20.0** kN/m^3

Design shear strength ϕ' = **24.2** deg

Angle of wall friction δ = **18.6** deg

Base material details

Firm clay

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

Design shear strength ϕ'_b = **24.2** deg

Design base friction δ_b = **18.6** deg

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

Using Coulomb theory

Active pressure coefficient for retained material

$$K_a = \sin(\alpha + \phi')^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta) \times [1 + \sqrt{(\sin(\phi' + \delta) \times \sin(\phi' - \beta) / (\sin(\alpha - \delta) \times \sin(\alpha + \beta)))}]^2) = \mathbf{0.369}$$

Passive pressure coefficient for base material

$$K_p = \sin(90 - \phi'_b)^2 / (\sin(90 - \delta_b) \times [1 - \sqrt{(\sin(\phi'_b + \delta_b) \times \sin(\phi'_b) / (\sin(90 + \delta_b)))}]^2) = \mathbf{4.187}$$

At-rest pressure

At-rest pressure for retained material $K_0 = 1 - \sin(\phi')$ = **0.590**

Loading details

Surcharge load on plan Surcharge = **10.0** kN/m^2

Applied vertical dead load on wall W_{dead} = **54.0** kN/m

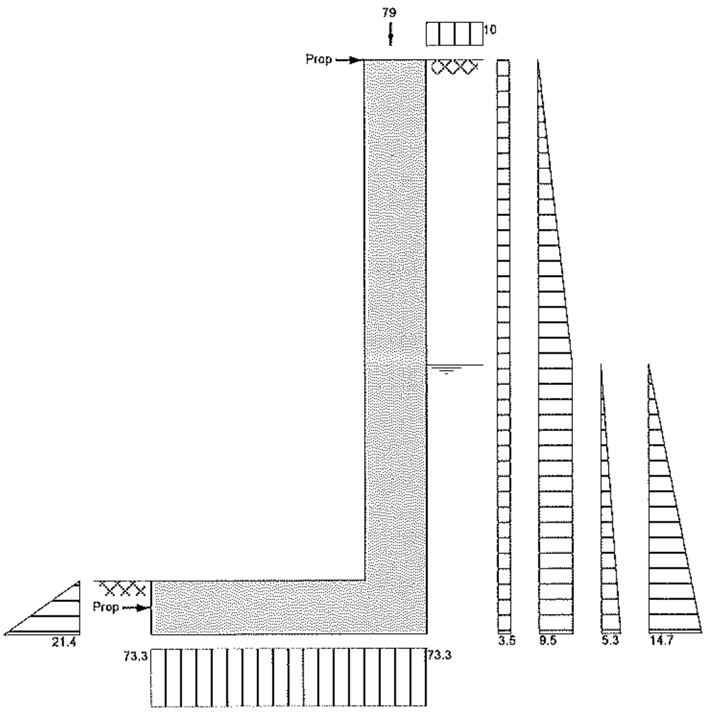
Applied vertical live load on wall W_{live} = **24.7** kN/m

Position of applied vertical load on wall l_{load} = **1350** mm

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

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

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



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

Vertical forces on wall

Wall stem $w_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall}$ = **24** kN/m

Wall base $w_{base} = l_{base} \times t_{base} \times \gamma_{base}$ = **11** kN/m

Applied vertical load $W_v = W_{dead} + W_{live}$ = **78.7** kN/m

Total vertical load $W_{total} = w_{wall} + w_{base} + W_v$ = **113.6** kN/m

Horizontal forces on wall

Surcharge $F_{sur} = K_a \times \cos(90 - \alpha + \delta) \times \text{Surcharge} \times h_{eff}$ = **11.2** kN/m

Moist backfill above water table $F_{m\_a} = 0.5 \times K_a \times \cos(90 - \alpha + \delta) \times \gamma_m \times (h_{eff} - h_{water})^2$ = **8.1** kN/m

Moist backfill below water table $F_{m\_b} = K_a \times \cos(90 - \alpha + \delta) \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **14.3** kN/m

Saturated backfill $F_s = 0.5 \times K_a \times \cos(90 - \alpha + \delta) \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **4** kN/m

Water $F_{water} = 0.5 \times h_{water}^2 \times \gamma_{water}$ = **11** kN/m

Total horizontal load $F_{total} = F_{sur} + F_{m\_a} + F_{m\_b} + F_s + F_{water}$ = **48.6** kN/m

Calculate total propping force

Passive resistance of soil in front of wall $F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **3.2** kN/m

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

F_{prop} = **15.5** kN/m

Overturning moments

Surcharge $M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **17.9** kNm/m

Moist backfill above water table $M_{m\_a} = F_{m\_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **16.7** kNm/m

Moist backfill below water table $M_{m\_b} = F_{m\_b} \times (h_{water} - 2 \times d_{ds}) / 2$ = **10.7** kNm/m

Saturated backfill $M_s = F_s \times (h_{water} - 3 \times d_{ds}) / 3$ = **2** kNm/m

Water $M_{water} = F_{water} \times (h_{water} - 3 \times d_{ds}) / 3$ = **5.5** kNm/m

Total overturning moment $M_{ot} = M_{sur} + M_{m\_a} + M_{m\_b} + M_s + M_{water}$ = **52.9** kNm/m

Restoring moments

Wall stem $M_{wall} = w_{wall} \times (l_{toe} + t_{wall} / 2)$ = **32.9** kNm/m

Wall base $M_{base} = w_{base} \times l_{base} / 2$ = **8.5** kNm/m

Design vertical dead load $M_{dead} = W_{dead} \times l_{load}$ = **72.9** kNm/m

Total restoring moment $M_{rest} = M_{wall} + M_{base} + M_{dead}$ = **114.3** kNm/m

Check bearing pressure

Total vertical reaction $R = W_{totel}$ = **113.6** kN/m

Distance to reaction $x_{bar} = l_{base} / 2$ = **775** mm

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

Reaction acts within middle third of base

Bearing pressure at toe $p_{toe} = (R / l_{base}) - (6 \times R \times e / l_{base}^2)$ = **73.3** kN/m^2

Bearing pressure at heel $p_{heel} = (R / l_{base}) + (6 \times R \times e / l_{base}^2)$ = **73.3** 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

$F_{prop\_top} = (M_{ot} - M_{rest} + R \times l_{base} / 2 - F_{prop} \times t_{base} / 2) / (h_{stem} + t_{base} / 2)$ = **7.953** kN/m

Propping force to base of wall $F_{prop\_base} = F_{prop} - F_{prop\_top}$ = **7.509** kN/m

RETAINING WALL DESIGN (BS 8002:1994)

TEDDS calculation version 1.2.01.06

Ultimate limit state load factors

Dead load factor γ_{f_d} = **1.4**

Live load factor γ_{f_l} = **1.6**

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

Factored vertical forces on wall

Wall stem $w_{wall\_f} = \gamma_{f\_d} \times h_{stem} \times t_{wall} \times \gamma_{wall}$ = **33.5** kN/m

Wall base $w_{base\_f} = \gamma_{f\_d} \times l_{base} \times t_{base} \times \gamma_{base}$ = **15.4** kN/m

Applied vertical load $W_{v\_f} = \gamma_{f\_d} \times W_{dead} + \gamma_{f\_l} \times W_{live}$ = **115.1** kN/m

Total vertical load $W_{total\_f} = w_{wall\_f} + w_{base\_f} + W_{v\_f}$ = **164** kN/m

Factored horizontal at-rest forces on wall

Surcharge $F_{sur\_f} = \gamma_{f\_l} \times K_0 \times \text{Surcharge} \times h_{eff}$ = **30.2** kN/m

Moist backfill above water table $F_{m\_a\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2$ = **19.1** kN/m

Moist backfill below water table $F_{m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **33.7** kN/m

Saturated backfill $F_{s\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **9.5** kN/m

Water $F_{water\_f} = \gamma_{f\_e} \times 0.5 \times h_{water}^2 \times \gamma_{water}$ = **15.5** kN/m

Total horizontal load $F_{total\_f} = F_{sur\_f} + F_{m\_a\_f} + F_{m\_b\_f} + F_{s\_f} + F_{water\_f}$ = **107.9** kN/m

Calculate total propping force

Passive resistance of soil in front of wall $F_{p\_f} = \gamma_{f\_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **4.5** kN/m

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

F_{prop_f} = **61.5** kN/m

Factored overturning moments

Surcharge $M_{sur\_f} = F_{sur\_f} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **48.3** kNm/m

Moist backfill above water table $M_{m\_a\_f} = F_{m\_a\_f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **39.5** kNm/m

Moist backfill below water table $M_{m\_b\_f} = F_{m\_b\_f} \times (h_{water} - 2 \times d_{ds}) / 2$ = **25.3** kNm/m

Saturated backfill $M_{s\_f} = F_{s\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **4.7** kNm/m

Water $M_{water\_f} = F_{water\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **7.7** kNm/m

Total overturning moment $M_{ot\_f} = M_{sur\_f} + M_{m\_a\_f} + M_{m\_b\_f} + M_{s\_f} + M_{water\_f}$ = **125.6** kNm/m

Restoring moments

Wall stem $M_{wall\_f} = w_{wall\_f} \times (l_{toe} + t_{wall} / 2)$ = **46.1** kNm/m

Wall base $M_{base\_f} = w_{base\_f} \times l_{base} / 2$ = **11.9** kNm/m

Design vertical load $M_{v\_f} = W_{v\_f} \times l_{load}$ = **155.4** kNm/m

Total restoring moment $M_{rest\_f} = M_{wall\_f} + M_{base\_f} + M_{v\_f}$ = **213.4** kNm/m

Factored bearing pressure

Total vertical reaction $R_f = W_{total\_f}$ = **164.0** kN/m

Distance to reaction $x_{bar\_f} = l_{base} / 2$ = **775** 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 $p_{toe\_f} = (R_f / l_{base}) - (6 \times R_f \times e_f / l_{base}^2)$ = **105.8** kN/m²

Bearing pressure at heel $p_{heel\_f} = (R_f / l_{base}) + (6 \times R_f \times e_f / l_{base}^2)$ = **105.8** kN/m²

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

Bearing pressure at stem / toe $p_{stem\_toe\_f} = \max(p_{toe\_f} - (rate \times l_{toe}), 0 \text{ kN/m}^2)$ = **105.8** kN/m²

Bearing pressure at mid stem $p_{stem\_mid\_f} = \max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall} / 2)), 0\ kN/m^2) = \mathbf{105.8}\ kN/m^2$

Bearing pressure at stem / heel $p_{stem\_heel\_f} = \max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall})), 0\ kN/m^2) = \mathbf{105.8}\ kN/m^2$

Calculate propping forces to top and base of wall

Propping force to top of wall

$$F_{prop\_top\_f} = (M_{ot\_f} - M_{rest\_f} + R_f \times l_{base} / 2 - F_{prop\_f} \times t_{base} / 2) / (h_{stem} + t_{base} / 2) = \mathbf{9.838}\ kN/m$$

Propping force to base of wall $F_{prop\_base\_f} = F_{prop\_f} - F_{prop\_top\_f} = \mathbf{51.702}\ kN/m$

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

Material properties

Characteristic strength of concrete $f_{cu} = \mathbf{35}\ N/mm^2$

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

Base details

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

Cover to reinforcement in toe $c_{toe} = \mathbf{50}\ mm$

Calculate shear for toe design

Shear from bearing pressure $V_{toe\_bear} = (p_{toe\_f} + p_{stem\_toe\_f}) \times l_{toe} / 2 = \mathbf{127}\ kN/m$

Shear from weight of base $V_{toe\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{toe} \times t_{base} = \mathbf{11.9}\ kN/m$

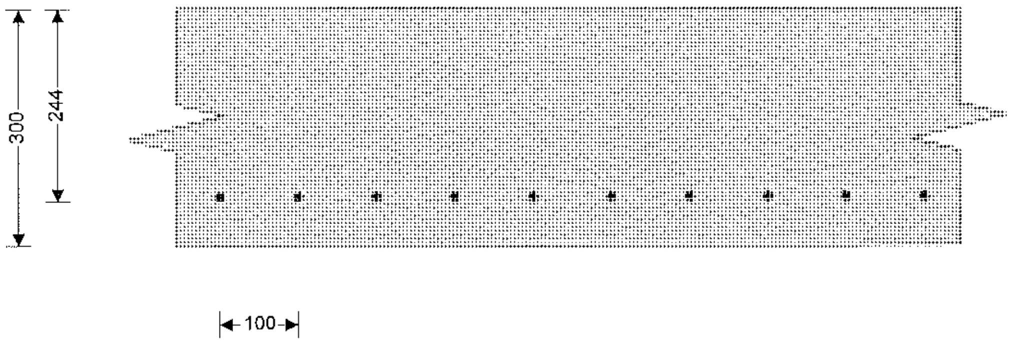
Total shear for toe design $V_{toe} = V_{toe\_bear} - V_{toe\_wt\_base} = \mathbf{115.1}\ kN/m$

Calculate moment for toe design

Moment from bearing pressure $M_{toe\_bear} = (2 \times p_{toe\_f} + p_{stem\_mid\_f}) \times (l_{toe} + t_{wall} / 2)^2 / 6 = \mathbf{100}\ kNm/m$

Moment from weight of base $M_{toe\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2 / 2) = \mathbf{9.4}\ kNm/m$

Total moment for toe design $M_{toe} = M_{toe\_bear} - M_{toe\_wt\_base} = \mathbf{90.7}\ kNm/m$



Check toe in bending

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

Depth of reinforcement $d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2) = \mathbf{244.0}\ mm$

Constant $K_{toe} = M_{toe} / (b \times d_{toe}^2 \times f_{cu}) = \mathbf{0.044}$

Compression reinforcement is not required

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

$z_{toe} = \mathbf{232}\ mm$

Area of tension reinforcement required $A_{s\_toe\_des} = M_{toe} / (0.87 \times f_y \times z_{toe}) = \mathbf{900}\ mm^2/m$

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

Area of tension reinforcement required $A_{s\_toe\_req} = \mathrm{Max}(A_{s\_toe\_des}, A_{s\_toe\_min}) = \mathbf{900}\ mm^2/m$

Reinforcement provided **12 mm dia.bars @ 100 mm centres**

Area of reinforcement provided $A_{s\_toe\_prov} = \mathbf{1131}\ mm^2/m$

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress $v_{toe} = V_{toe} / (b \times d_{toe})$ = **0.472** N/mm^2

Allowable shear stress $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1 \text{ N/mm}^2)}, 5) \times 1 \text{ N/mm}^2$ = **4.733** 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} = **0.619** 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} = **35** N/mm^2

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

Wall details

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

Cover to reinforcement in stem c_{stem} = **50** mm

Cover to reinforcement in wall c_{wall} = **50** mm

Factored horizontal at-rest forces on stem

Surcharge $F_{s\_sur\_f} = \gamma_{f\_l} \times K_0 \times \text{Surcharge} \times (h_{eff} - t_{base} - d_{ds})$ = **27.4** kN/m

Moist backfill above water table $F_{s\_m\_a\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2$ = **19.1** kN/m

Moist backfill below water table $F_{s\_m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat}) \times h_{sat}$ = **27** kN/m

Saturated backfill $F_{s\_s\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{sat}^2$ = **6.1** kN/m

Water $F_{s\_water\_f} = 0.5 \times \gamma_{f\_e} \times \gamma_{water} \times h_{sat}^2$ = **9.9** kN/m

Calculate shear for stem design

Surcharge $V_{s\_sur\_f} = 5 \times F_{s\_sur\_f} / 8$ = **17.1** kN/m

Moist backfill above water table $V_{s\_m\_a\_f} = F_{s\_m\_a\_f} \times b_l \times ((5 \times L^2) - b_l^2) / (5 \times L^3)$ = **10** kN/m

Moist backfill below water table $V_{s\_m\_b\_f} = F_{s\_m\_b\_f} \times (8 - (n^2 \times (4 - n))) / 8$ = **24.6** kN/m

Saturated backfill $V_{s\_s\_f} = F_{s\_s\_f} \times (1 - (a_l^2 \times ((5 \times L) - a_l) / (20 \times L^3)))$ = **5.8** kN/m

Water $V_{s\_water\_f} = F_{s\_water\_f} \times (1 - (a_l^2 \times ((5 \times L) - a_l) / (20 \times L^3)))$ = **9.4** kN/m

Total shear for stem design $V_{stem} = V_{s\_sur\_f} + V_{s\_m\_a\_f} + V_{s\_m\_b\_f} + V_{s\_s\_f} + V_{s\_water\_f}$ = **66.9** kN/m

Calculate moment for stem design

Surcharge $M_{s\_sur} = F_{s\_sur\_f} \times L / 8$ = **10.4** kNm/m

Moist backfill above water table $M_{s\_m\_a} = F_{s\_m\_a\_f} \times b_l \times ((5 \times L^2) - (3 \times b_l^2)) / (15 \times L^2)$ = **8.8** kNm/m

Moist backfill below water table $M_{s\_m\_b} = F_{s\_m\_b\_f} \times a_l \times (2 - n)^2 / 8$ = **11** kNm/m

Saturated backfill $M_{s\_s} = F_{s\_s\_f} \times a_l \times ((3 \times a_l^2) - (15 \times a_l \times L) + (20 \times L^2)) / (60 \times L^2)$ = **1.9** kNm/m

Water $M_{s\_water} = F_{s\_watar\_f} \times a_l \times ((3 \times a_l^2) - (15 \times a_l \times L) + (20 \times L^2)) / (60 \times L^2)$ = **3.1** kNm/m

Total moment for stem design $M_{stem} = M_{s\_sur} + M_{s\_m\_a} + M_{s\_m\_b} + M_{s\_s} + M_{s\_water}$ = **35.3** kNm/m

Calculate moment for wall design

Surcharge $M_{w\_sur} = 9 \times F_{s\_sur\_f} \times L / 128$ = **5.9** kNm/m

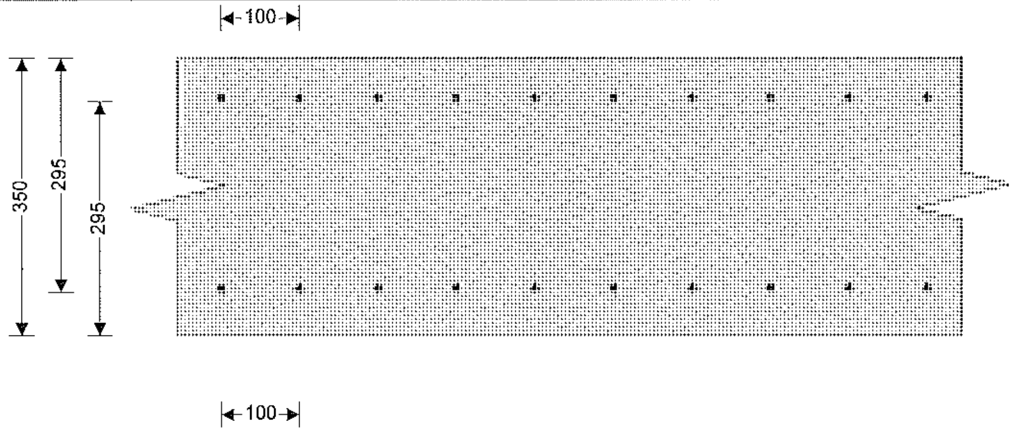
Moist backfill above water table $M_{w\_m\_a} = F_{s\_m\_a\_f} \times 0.577 \times b_l \times [(b_l^3 + 5 \times a_l \times L^2) / (5 \times L^3) - 0.577^2/3]$ = **6.9**
kNm/m

Moist backfill below water table $M_{w\_m\_b} = F_{s\_m\_b\_f} \times a_l \times [((8 - n^2 \times (4 - n))^2 / 16) - 4 + n \times (4 - n)] / 8$ = **4.1** kNm/m

Saturated backfill $M_{w\_s} = F_{s\_s\_f} \times [a_l^2 \times x \times ((5 \times L) - a_l) / (20 \times L^3) - (x - b_l)^3 / (3 \times a_l^2)]$ = **0.5** kNm/m

Water $M_{w\_water} = F_{s\_water\_f} \times [a_l^2 \times x \times ((5 \times L) - a_l) / (20 \times L^3) - (x - b_l)^3 / (3 \times a_l^2)]$ = **0.8**
kNm/m

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



Check wall stem in bending

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

Depth of reinforcement — $d_{stem} = t_{wall} - c_{stem} - (\phi_{stem} / 2)$ = **295.0** mm

Constant — $K_{stem} = M_{stem} / (b \times d_{stem}^2 \times f_{cu})$ = **0.012**

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} = **280** mm

Area of tension reinforcement required — $A_{s\_stem\_des} = M_{stem} / (0.87 \times f_y \times z_{stem})$ = **289** mm^2/m

Minimum area of tension reinforcement — $A_{s\_stem\_min} = k \times b \times t_{wall}$ = **455** mm^2/m

Area of tension reinforcement required — $A_{s\_stem\_req} = \mathrm{Max}(A_{s\_stem\_des}, A_{s\_stem\_min})$ = **455** mm^2/m

Reinforcement provided — **B785 mesh**

Area of reinforcement provided — $A_{s\_stem\_prov}$ = **785** mm^2/m

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress — $v_{stem} = V_{stem} / (b \times d_{stem})$ = **0.227** N/mm^2

Allowable shear stress — $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1 \text{ N/mm}^2)}, 5) \times 1 \text{ N/mm}^2$ = **4.733** 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} = **0.491** N/mm^2

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

Check mid height of wall in bending

Depth of reinforcement — $d_{wall} = t_{wall} - c_{wall} - (\phi_{wall} / 2)$ = **295.0** mm

Constant — $K_{wall} = M_{wall} / (b \times d_{wall}^2 \times f_{cu})$ = **0.006**

Compression reinforcement is not required

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

z_{wall} = **280** mm

Area of tension reinforcement required — $A_{s\_wall\_des} = M_{wall} / (0.87 \times f_y \times z_{wall})$ = **149** mm^2/m

Minimum area of tension reinforcement — $A_{s\_wall\_min} = k \times b \times t_{wall}$ = **455** mm^2/m

Area of tension reinforcement required — $A_{s\_wall\_req} = \mathrm{Max}(A_{s\_wall\_des}, A_{s\_wall\_min})$ = **455** mm^2/m

Reinforcement provided — **B785 mesh**

Area of reinforcement provided — $A_{s\_wall\_prov}$ = **785** mm^2/m

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

Check retaining wall deflection

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

Design service stress $f_s = 2 \times f_y \times A_{s\_stem\_req} / (3 \times A_{s\_stem\_prov})$ = **193.1** N/mm²

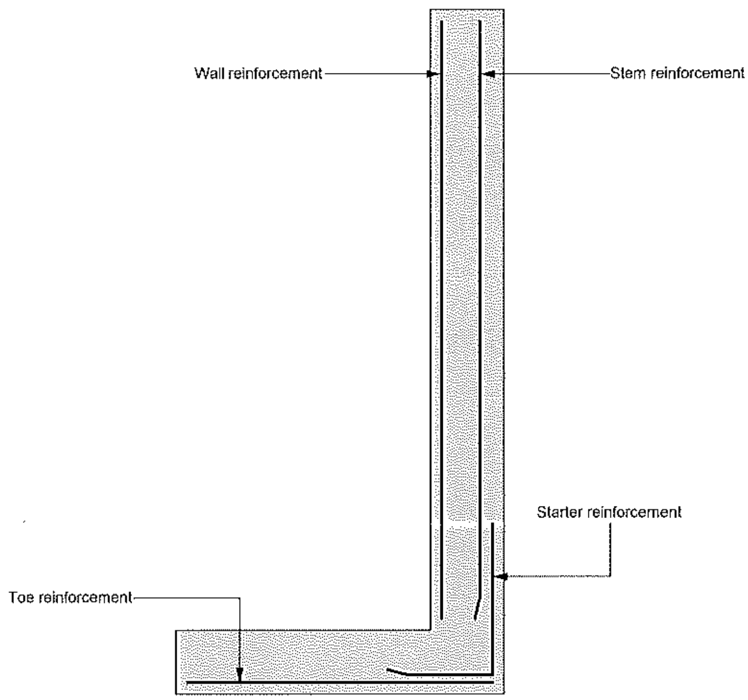
Modification factor $factor_{tens} = \min(0.55 + (477\ N/mm^2 - f_s)/(120 \times (0.9\ N/mm^2 + (M_{stem}/(b \times d_{stem}^2)))),2)$ = **2.00**

Maximum span/effective depth ratio $ratio_{max} = ratio_{bas} \times factor_{tens}$ = **40.00**

Actual span/effective depth ratio $ratio_{act} = h_{stem} / d_{stem}$ = **9.83**

PASS - Span to depth ratio is acceptable

__ndicative retaining wall reinforcement diagram__



Toe bars - 12 mm dia.@ 100 mm centres - (1131 mm²/m)
Wall mesh - B785 - (785 mm²/m)
Stem mesh - B785 - (785 mm²/m)

DESIGN FOR HEAVE.

LOADING

KNOWN SOIL = 18 × 2.9 m = 52 kN/m² TOTAL

SAY 50% DURING CONSTRUCTION = 52/2 = 26 kN/m²

DESIGN LOAD = 26 × 1.4 = 36.4 kN/m²

BM = 36 × 4.3²/8 = 82.2 kNm (ULT).

d = 300 − 50 − 6 = 244 mm.

M/bd²fcu = 82.2 × 10⁶ / 10³ × 244² × 35 = 0.039   a = 0.94

Ast = 82.2 × 10⁶ / 0.95 × 0.94 × 500 × 244 = 754 mm²/m

USE 2 LAYERS OF MESH TOP NESTED

SHEAR

V/bd = 36.4 × 2.15 × 10³ / 10³ × 244 = 0.149 N/mm²

100As/bd = 78500 / 10³ × 244 = 0.32   Vc = 0.5 N/mm² > 0.14

∴ OK IN SHEAR

SPAN/DEPTH = 4300/244 = 17.5 < 20 ∴ OK

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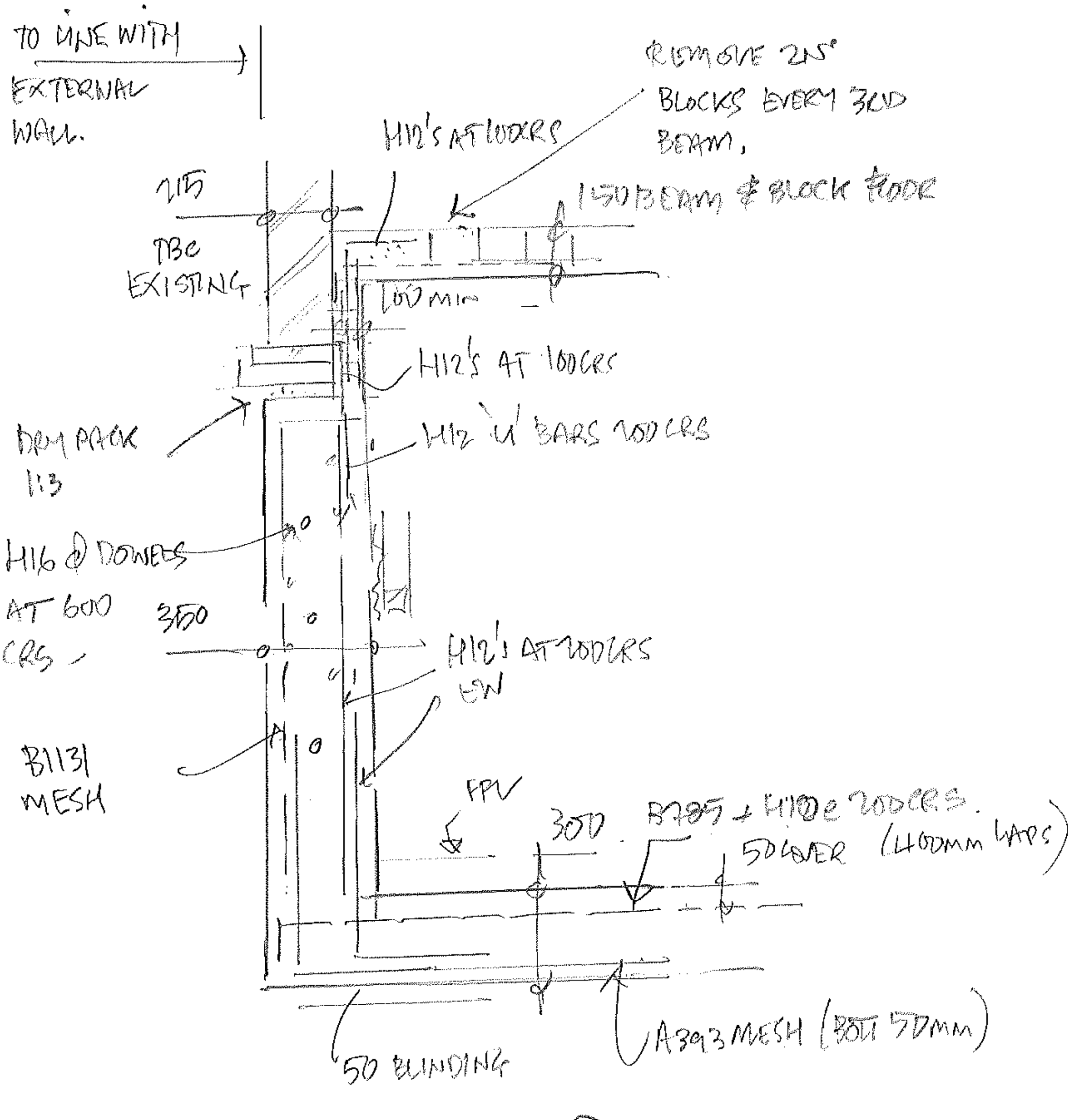
Project				Job Ref.	
25 BATHGATE MEWS LONDON W2				20.347	
Part of Structure				Sheet	
PROPOSED NEW BASEMENT				Page 39 of 47	
Calc. by	Date	Chck'd by	Date	App'd by	Date
JW	DEC 20				

Ref.	Calculations	Output



SECTION WALL (A).

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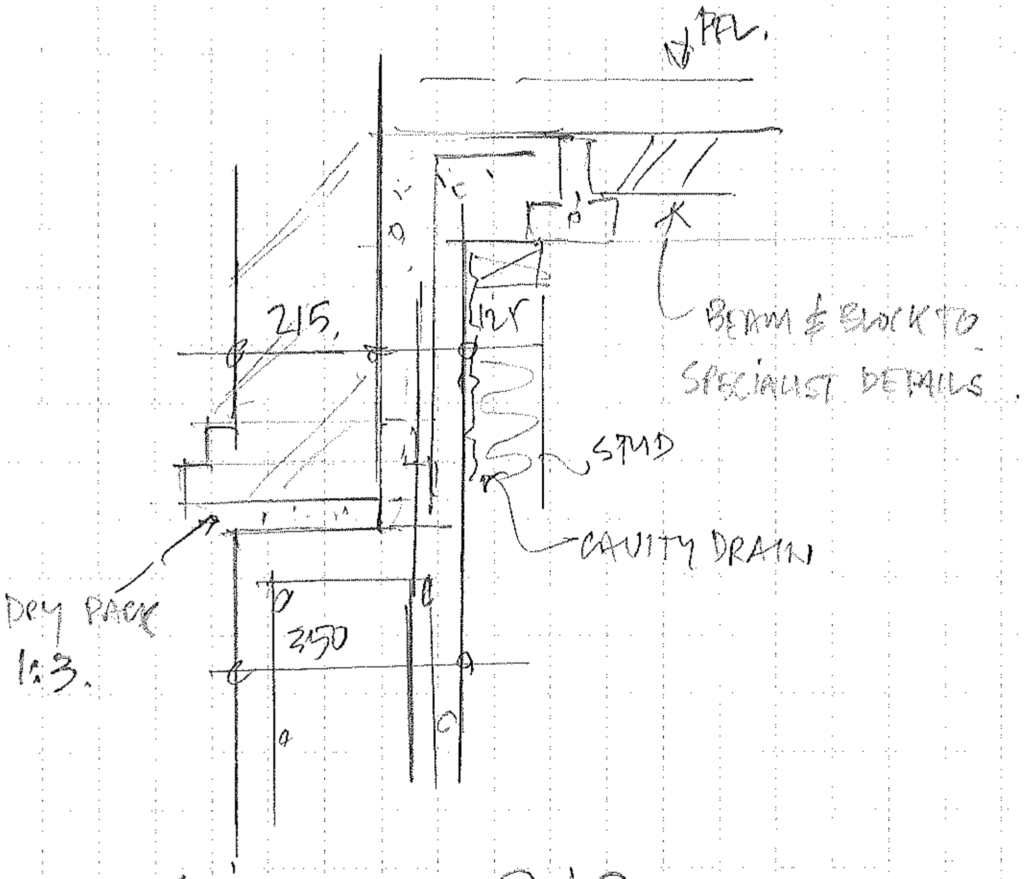
e-mail: info@anddesigns.co.uk

Project: 25 BATHGATE MEWS LONDON W2				Job Ref. 20.347	
Part of Structure: PROPOSED BASEMENT				SPage 40 of 47	
Calc. by: jw	Date	Chck'd by:	Date	App'd by:	Date

WALL (B) & (C) SIMILAR TO (A)



SECTION TOP WALL (B) & (C).

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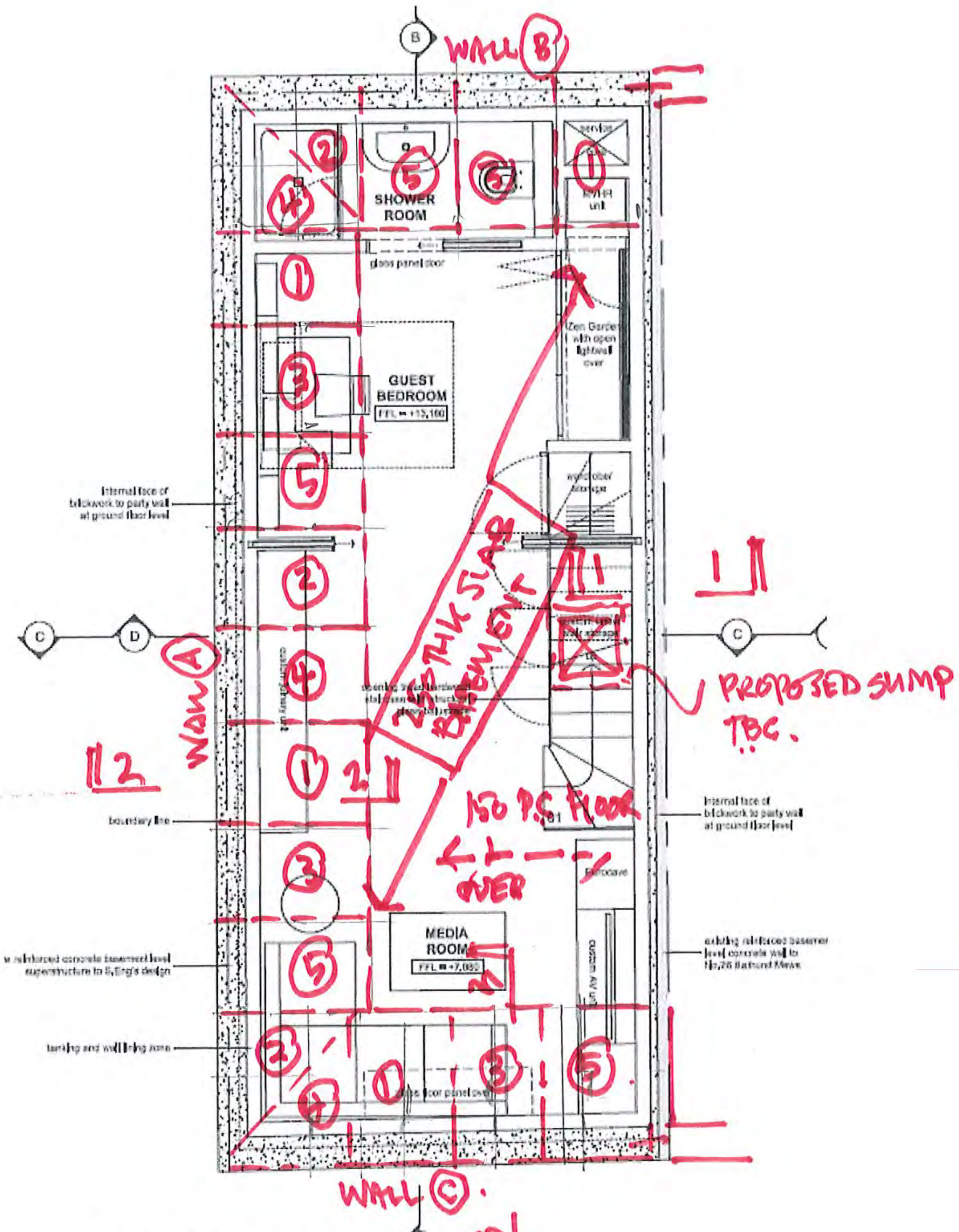
Project				Job Ref.	
25 BATHURST MEWS W2				20.347	
Part of Structure				Sheet No./rev.	
PROPOSED BASEMENT				SK01	
Calc. by	Date	Chck'd by	Date	App'd by	Date

Ref.	Calculations	Output



BASEMENT PLAN

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	Part of Structure PROPOSED GRD FLOOR				Sheet No./rev. SK 02	
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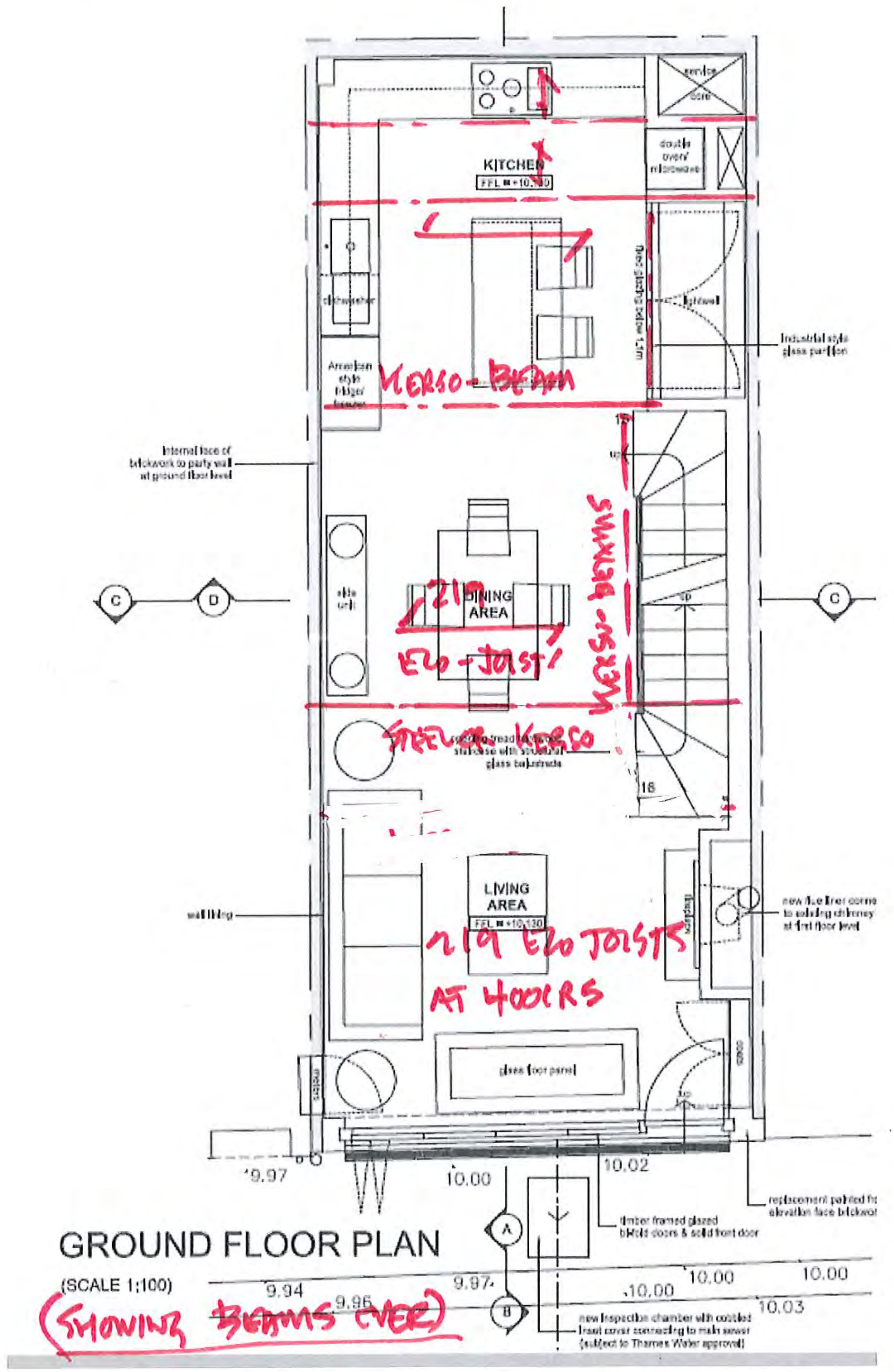
Ref.	Calculations	Output



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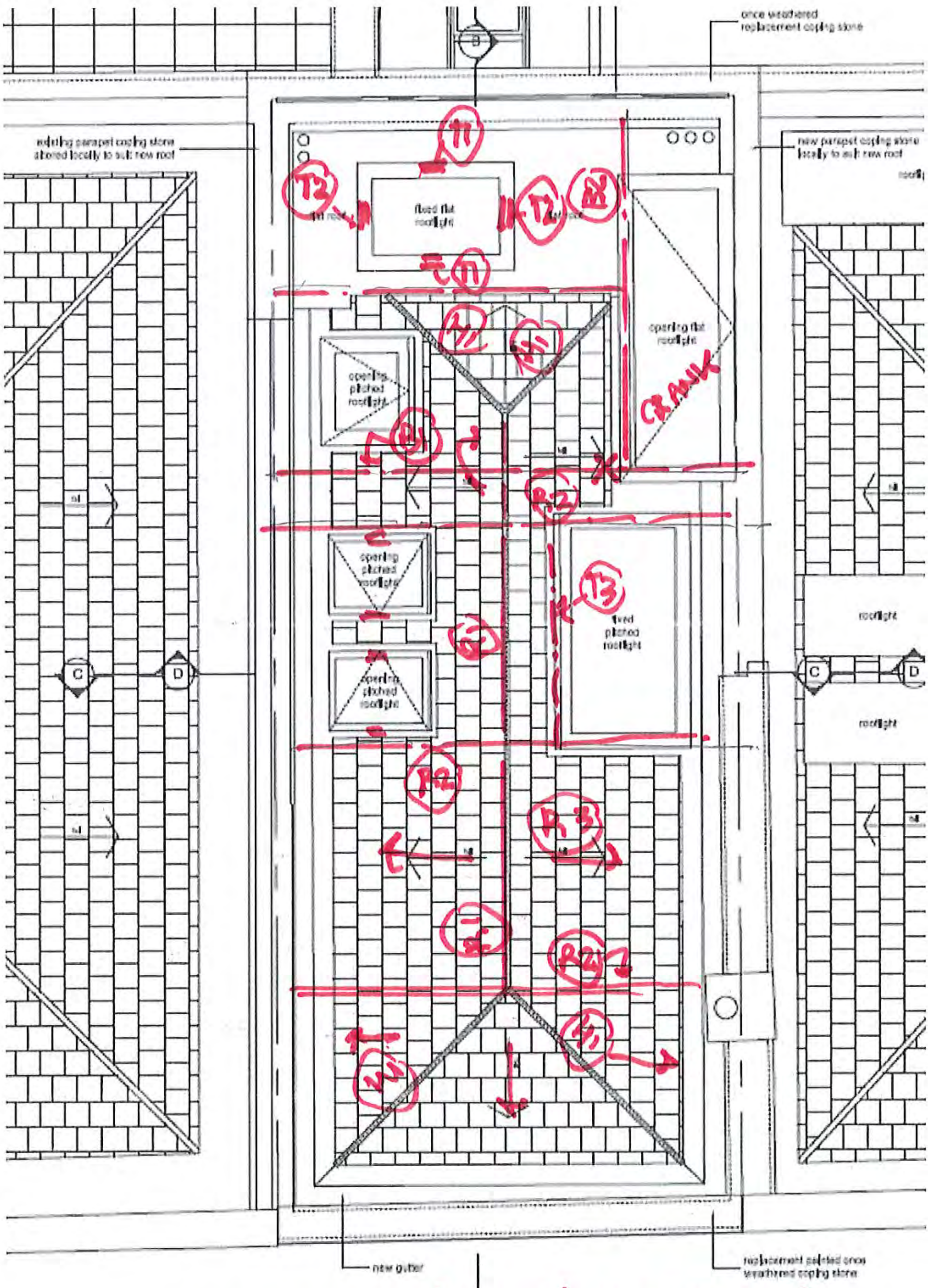
Project				Job Ref.	
25 BATHURST MEWS W2				20.347	
Part of Structure				Sheet No./rev.	
PROPOSED GRD FLOOR				SK03	
Calc. by	Date	Chck'd by	Date	App'd by	Date

Ref.	Calculations	Output



ROOF PLAN (SHOWING ROOF DETAILS)

(SCALE 1:100)

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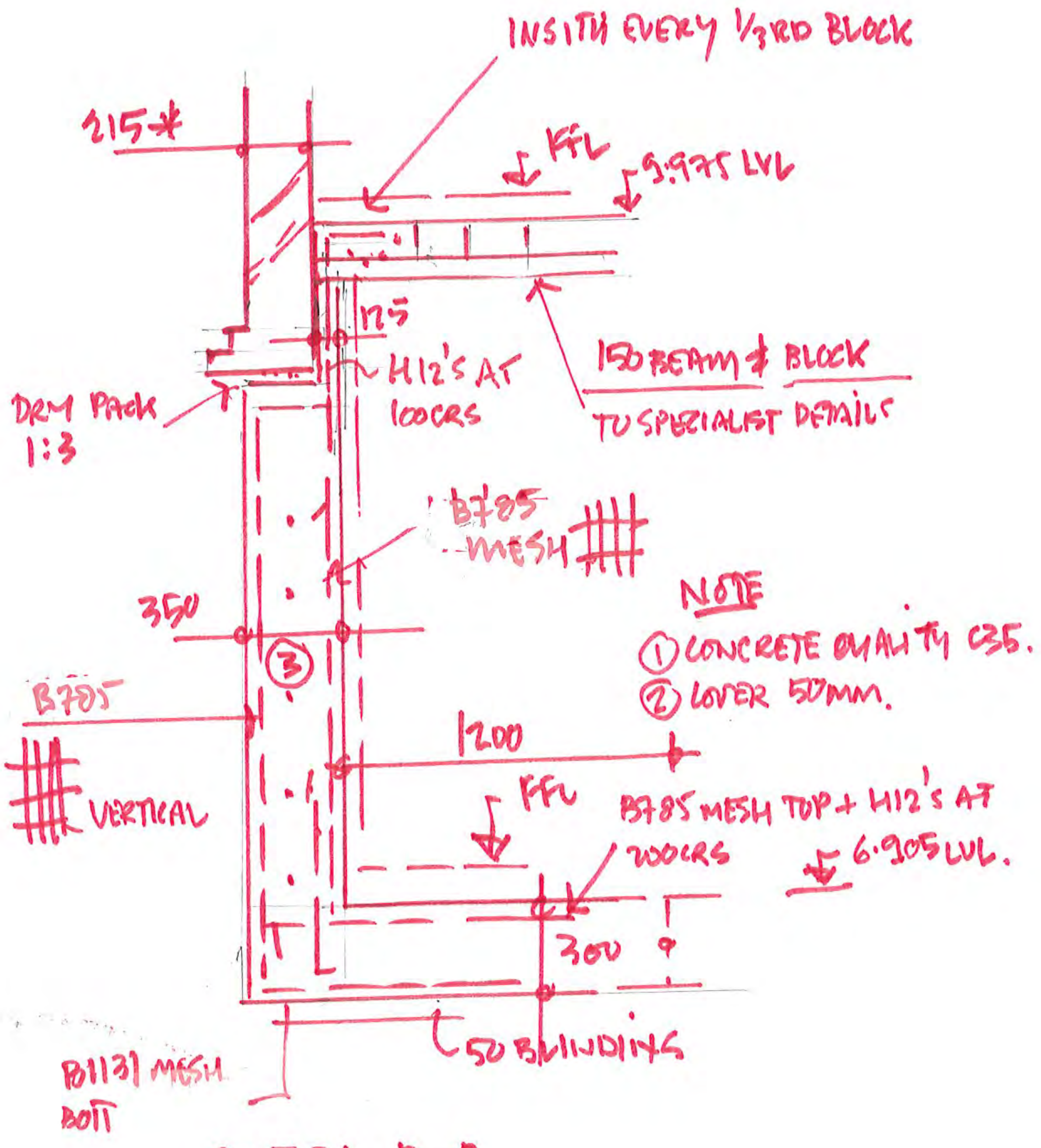
Project				Job Ref.	
25 BATHGATE MEWS LONDON W2				20.347	
Part of Structure: PROPOSED NEW BASEMENT				Sheet No./rev.: SK 04	
Calc. by: JW	Date: DEC 20	Chck'd by	Date	App'd by	Date

Ref.	Calculations	Output



SECTION 2-2

(SECTION 3-3 SIMILAR)

(NTS)

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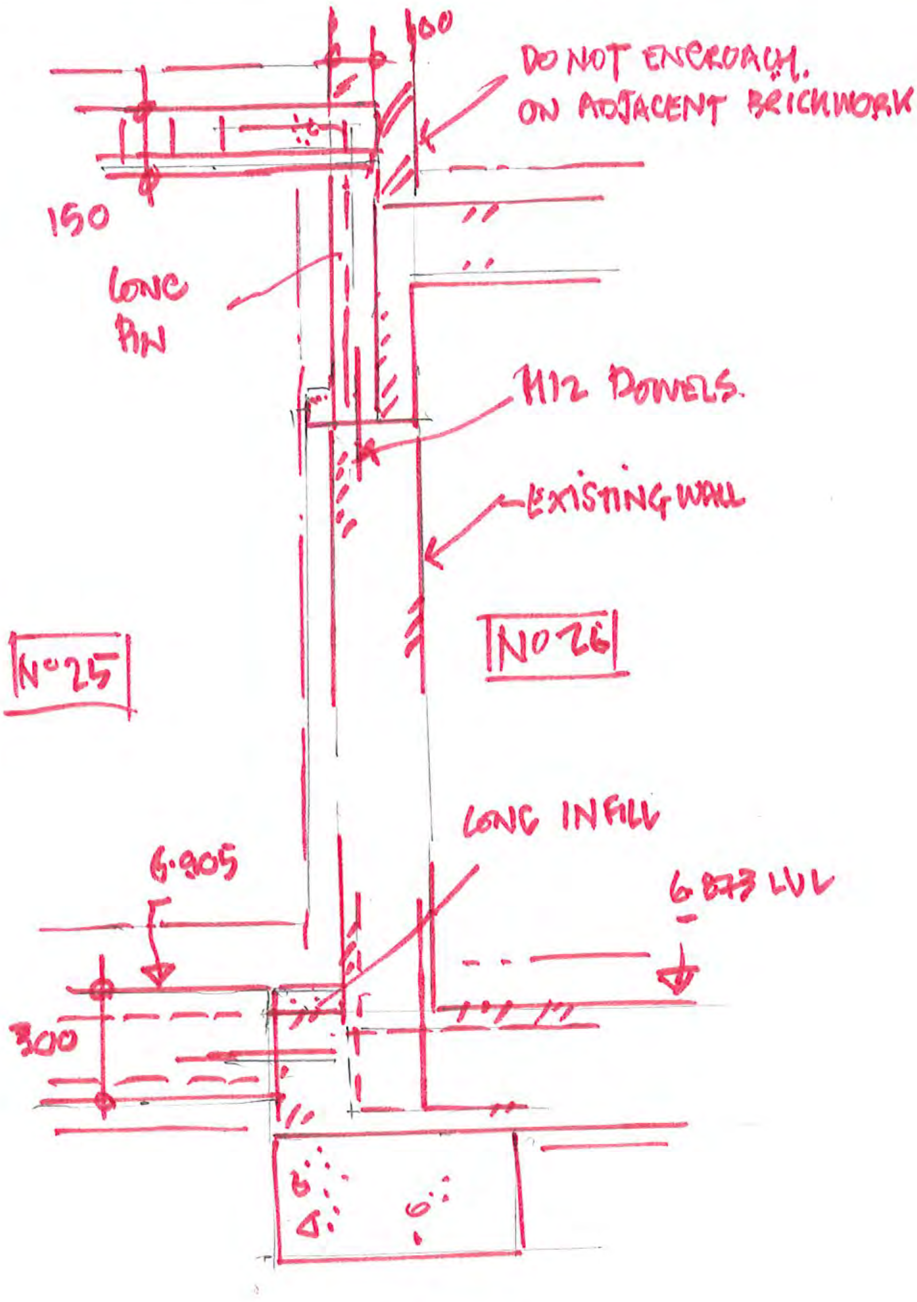
	Part of Structure PROPOSED NEW BASEMENT			Sheet No./rev. SK 05	
	Calc. by JW	Date DEC 20	Chck'd by	Date	App'd by	Date

Ref.	Calculations	Output



SECTION 1-1

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Appendix C
Underpin method statement

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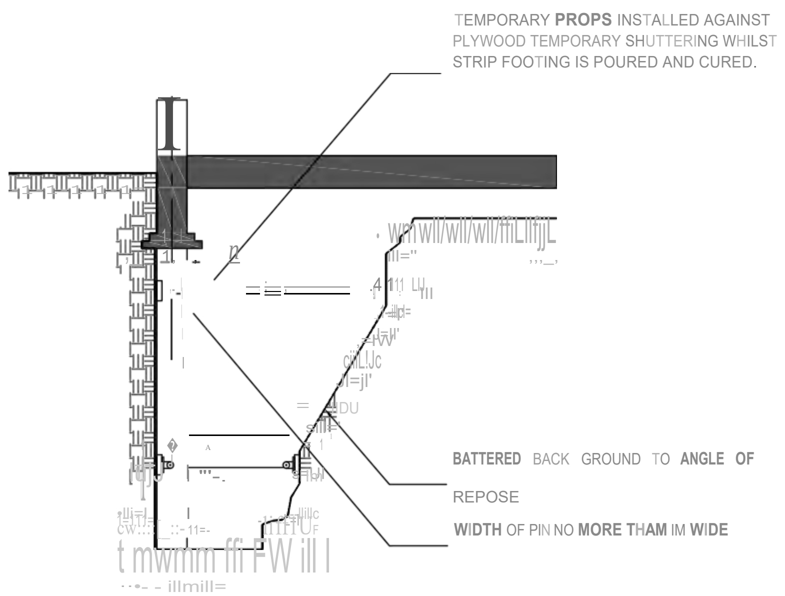
Email: info@anddesigns.co.uk
Company Registration No.3401843, VAT No.757 0489 03
Director: Jeff Walker CEng MIStructE



STAGE 1

POUR STRIP FOUNDATION

METHOD STATEMENT

UNDERPINNING

EACH PIN IS EXCAVATED AND IS NO MORE THAN IM IN WIDTH ANO IS POURED STRICTLY IN LINE **WITH THE** SEQUENC E AN O **THE** STRUC TURAL ENGINEERS DETAILS WITH PROPS INSTALLED, 4 FOR EACH PIN ENSURE THAT THE THICKNESS OF THE UNDERP IN MATCHES THE THICKNESS OF THE PARTY WALL UNLESS SHOWN OTHERWISE AS THE EXCAVAT ION FOR EACH UNDERPIN PROGRESSES THE THICKNESS ANO DEPTH OF **THE** PIN WILL BE CAREFULLY MON ITORED, ENSURING A VERTICAL AND WHERE POSSIBLE SMOOTH SHUTTERING FACE AGAINST **THE** SUBSTRATE SOIL. **EACH** PIN **WILL** BE POURED IN 4 STAGES AS FOLLOWS

A THE REINFORCEMENT WILL BE INSTALLED IN THE TOE SECTION - REFER TO STRUCTURAL ENGINEERS DETAILS. THE TOE WILL BE POURED **WITH** SHUTTERING PROPPED **AT** HIGH AND LOW **LEVEL AT THE** BACK OF **THE** PIN **IF** NECESSARY (GROUND COND ITIONS **WILL** DICTATE THIS) TO STOP SPOIL FALLING INTO THE EXCAVATION.

B. 24 HOURS AFTER THE TOE HAS BEEN POURED MESH **WILL** BE INSTALLED TO THE VERTICAL SECTION (REFER TO STRUC TURAL ENGINEERS DETAILS) SHUTTERING WILL **BE** INSTALLED ON **THE** NEAR SIDE OF **THE** PIN ANO PROPPED USING ACRO PROPS AT HIGH AND LOW LEVEL (4 OR 6 IN TOTAL) **THE** VERTICAL SECTION OF THE PIN WILL BE POURED

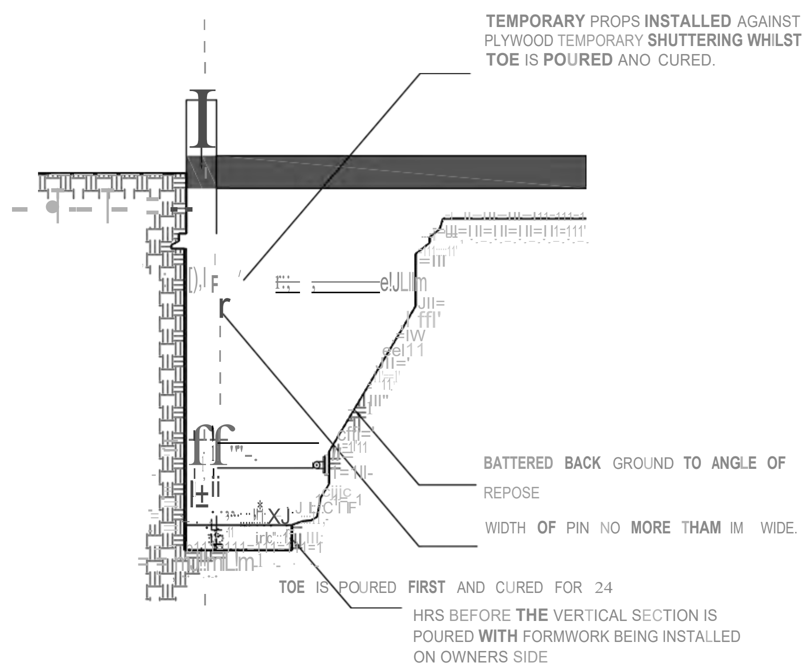
C. 48 HOURS AFTER **THE** PIN HAS BEEN POURED, **THE** PROPS AND SHUTTERING CAN BE REMOVED BEFORE THE NEXT PIN IN THE SEQUENCE (NOT ADJACENT) IS STAPTED. FINALLY 75MM OF DRYPACKING IS RAMMED IN TO THE GAP BETWEEN **THE** TOP OF THE PIN AND THE UNDERSIDE OF **THE** EXISTING FOUNDATION WITH THE EXPOSED SECTION OF THE FOOTING ON **THE** NEARSIDE BEING REMOVED. TEMPORARY PROPP ING (ACRO PROPS) IS INSTALLED TO SUPPORT **THE** PIN ONCE **THE** SHUTTERING HAS BEEN REMOV ED, **WITH** 2 ACROSS **AT** HIGH **LEVEL** AND 2 ACROSS **AT** LOW **LEVEL** PER PIN.

2. **THE** CENTRAL AREA OF EXCAVATION SHALL NOT BE CARRIED OUT UNTIL THE PERIMETER UNDERPINNED RETAINING WALLS **HAVE** BEEN COMPLETED.

J. THE CENTRAL SECTION WILL NOW BE EXCAVATED AND THIS **WILL** BE DONE IN 3 SECTION S TO AVOID ANY SLIPPAGE. **LATERAL** MABEY BRACING STRUTS OR SIMILAR **WILL** BE **INSTALLED** TO COUNTER **THIS. THE** RE-INFORCED MESH WILL BE PREPARED AN O LAID ANO WILL BE OVERLAPPED TO ENSURE INTEGRITY. THE BASEMENT SLAB IS CAST AS DETAILED BY **THE** STRUC TURAL ENGINEER AND **WILL** BE CAST IN 3 SECTIONS, WITH ONLY I SECTION BEING EXCAVATED ANO POURED **AT** A TIME

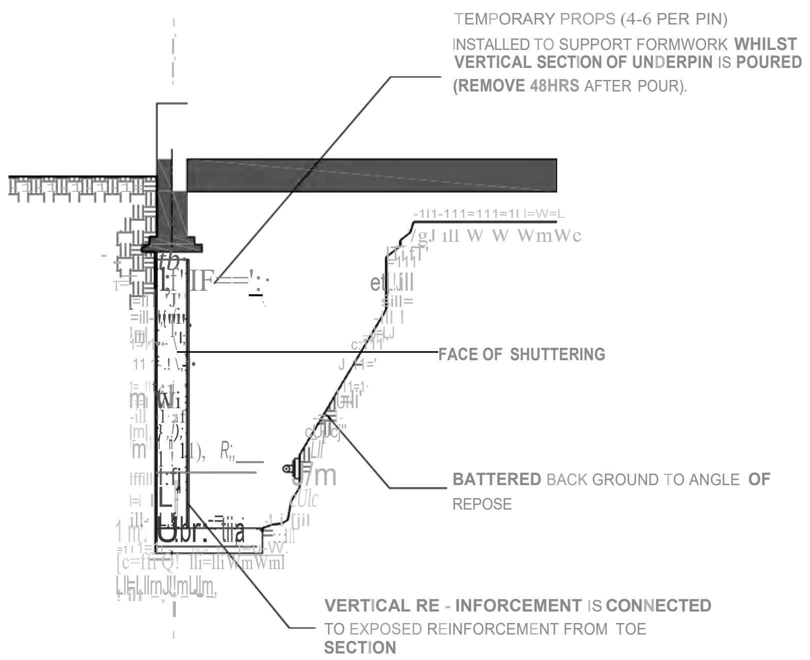
4. ONCE **THE** CONCRETE SLAB HAS BEEN POURED, **THE** STRUTS WILL BE REMOVED 48 HOURS AFTER THE POUR AND **THE** SEQUENC E IS FOLLOWED AGAIN FOR THE NEXT SECTION

FOR CENTRAL AREA OF EXCAVATION REFER TO DWG 1 5.052. T2.CI



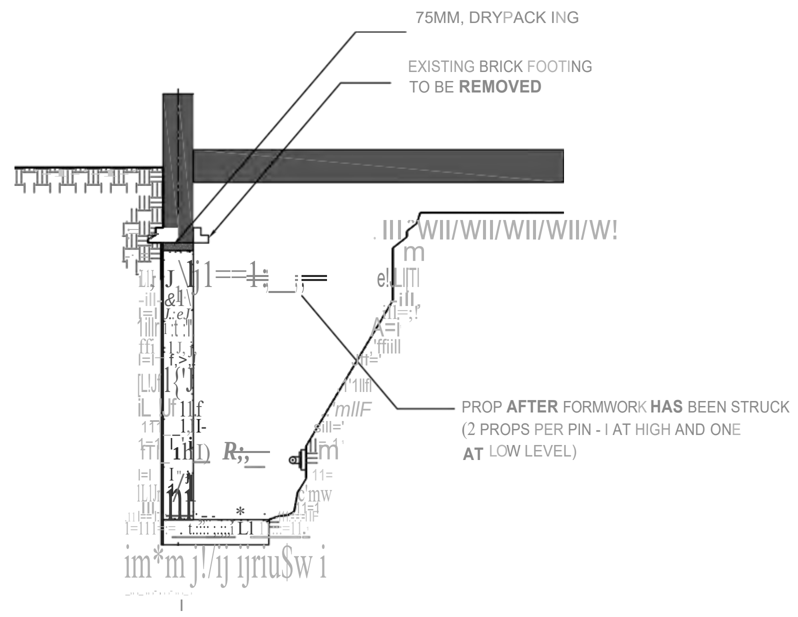
STAGE 2

POUR TOE / BASE FOUNDATION



STAGE 3

POUR VERTICAL PIN TIED INTO TOE



STAGE 4

DRY PACK TO TOP OF PIN AND SUPPORT PIN

PI	PRELIMINARY	
Rev.	Description	Date

AND DESIGNS LTD

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Project: TYPICAL

Title: STANDARD UNDERPINNING METHODOLOGY

Scale: AS SHOWN @ A1	Job No. 1 6.303
Date: NOV. 2016	
Dwn. by: DG / Chkd by: JAL	Dwg No. SK-02