APPENDIX E

STRUCTURAL CALCULATIONS

56 DARTMOUTH PARK ROAD - INTRODUCTION.

These calculations cover the main permanent and temporary works elements necessary to form a basement under the front 'dining' room of this double fronted property extending the present cellar area & lowering the floor to provide better headroom.

The investigations found previous underpinning to the front & flank walls to the property, effectively 'forming the basement walls'. If the mass concrete could act as retaining walls was checked: these were not able to take the permanent loading - some surprise as it is likely the present cellar/retaining walls are thinner masonry. However, a new R.C. retaining structure, propped by the base slab & new ground slab is designed. Elsewhere, the existing brick walls are to be made good, (lined if necessary) & underpinned to provide the necessary depth & a better spread than present as there are some signs of movement where loads are particularly high.

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Project: 56 D. Pk Rd
Project No: 180447
Sheet No.
Title: calcs. intro continued.
Date
Revision
Engineer: HH
Checked

Rev Date Description

All the calculations are & will be to the relevant British Standards & Regulations, taking into account the information provided by the SI & investigations on the existing structure. Preliminary design to the ground floor has been undertaken, however as the final arrangement is to include internal alterations which have not yet been confirmed, this are necessarily not approached in detail, and will be included in tender & detailed design once the upper arrangements are frozen.

What follows is:

- loading down of typical wall (external)
- check on existing underpinning.
- new (propped) r.c retaining wall design.
- design of whaling beams given the propping force from above.
- design of diagonal props given loading from above.

All final temporary works will be by the contractor, submitted to Conisbee & Building Control for checking.

[signature]
MSc BEng(Hons) MIStructE

7.5m

EDWARDS RENSEN ARCHITECTS

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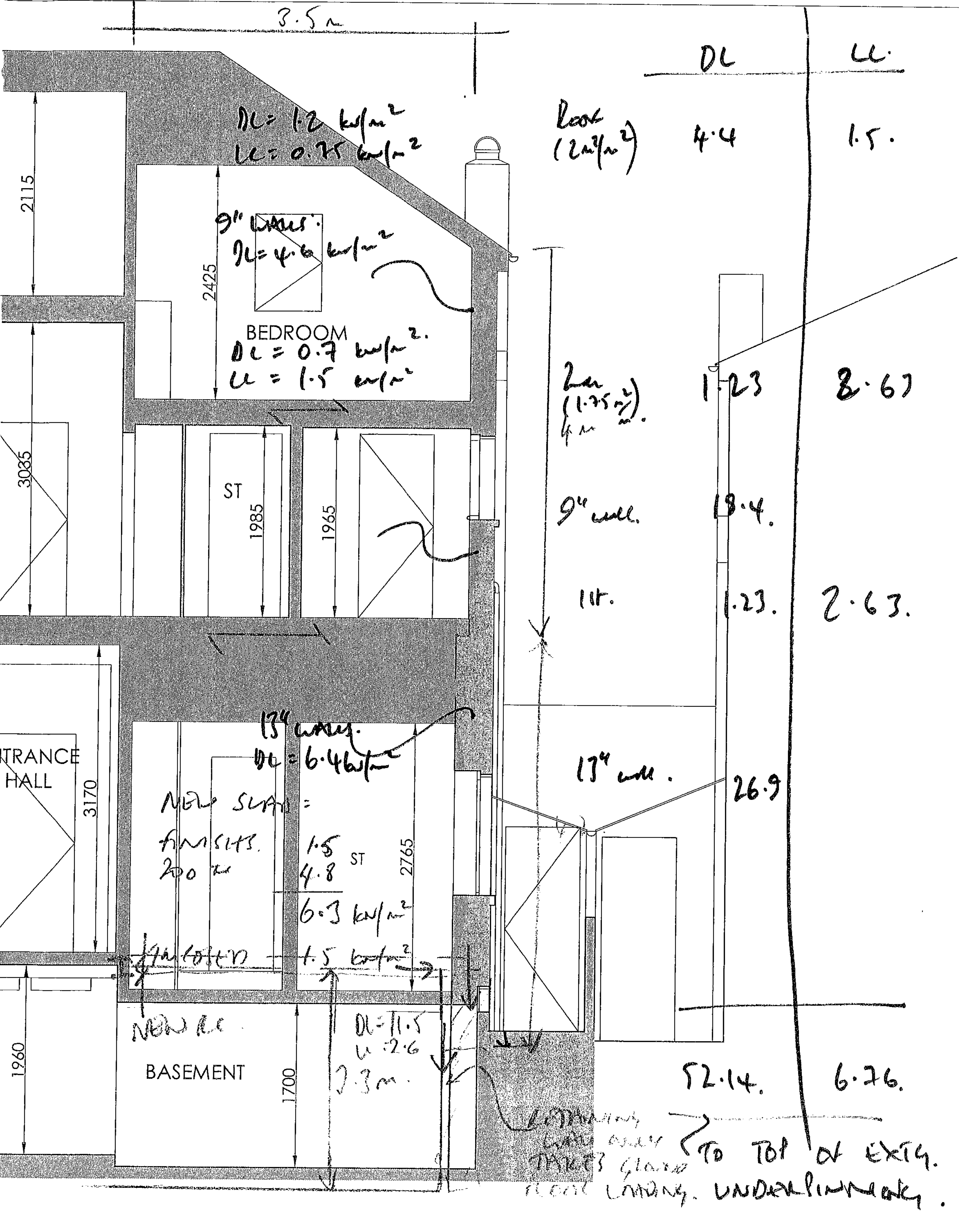
Client: Rachel Jupp & Jonatha Wald

Project: 56 Dartmouth Park Road, London, NW5 1SN

Drawing number: SK-41
Drawing Title: **PROPOSED SECTION C**
Phase: Initial Design
Scale: 1:50 @ A3



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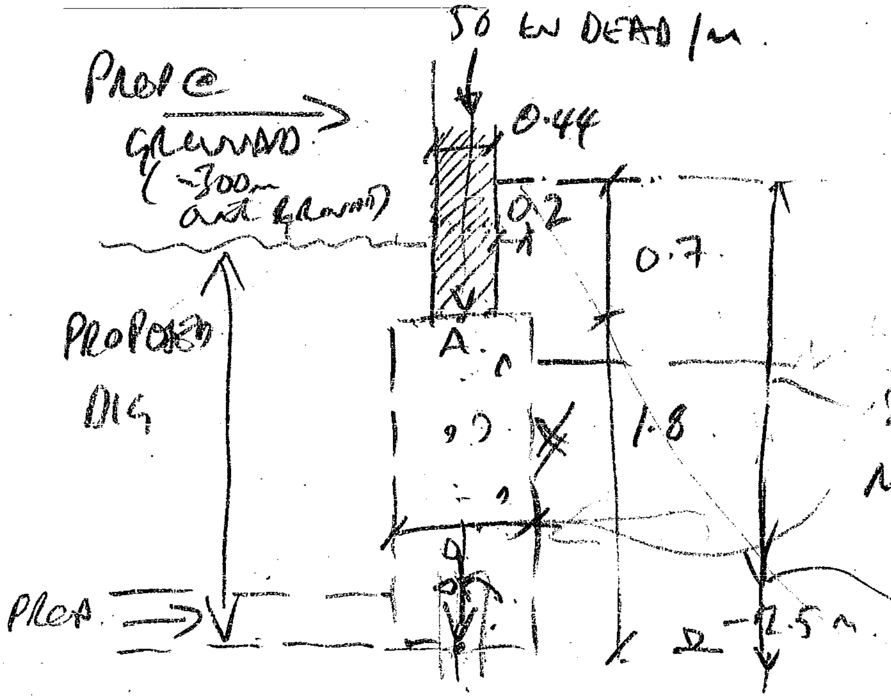
Project	Project No	Sheet No
56 DARTMOUTH PARK ROAD.	180447.	
Title	**Date**	**Revision**
EXISTING U-P AB RETAINING WALL CHECK.	OCT.	
	Engineer	**Checked**
	HH	

Rev Date Description



γ^0 = 20.
γ = 19 kN/m²
ϕ = 22
(DESIGN ONLY) — ACTUAL TABLE BELOW.

2m - MADE GRD. (BACK FILL)
MIN. 0.60 THK
LIKELY 0.8 m THK.

→ 2.7 STIFF CLAY
γ = 18 kN/m²
ϕ = 23.
N = 18.33

K_A = 0.45 K_P = 2.20

		P	W	L (distance)	M
Active pressure	$P_a = \frac{1}{2} \times 0.45 \times 19 \times 2.5^2$	26.7		0.83	22.03
Self weight	80kN + 0.8×23×1.8		83.12		
Wall friction	23 tan 20° (8.37)		8.37	0.5	4.2
		26.7	91.5		26.22

Load eccentricity 26.2/91.5 = 0.29m.
middle 1/3 limit 0.8/6 = 0.133 m. e = 0.29 > 0.133m — outside middle third!

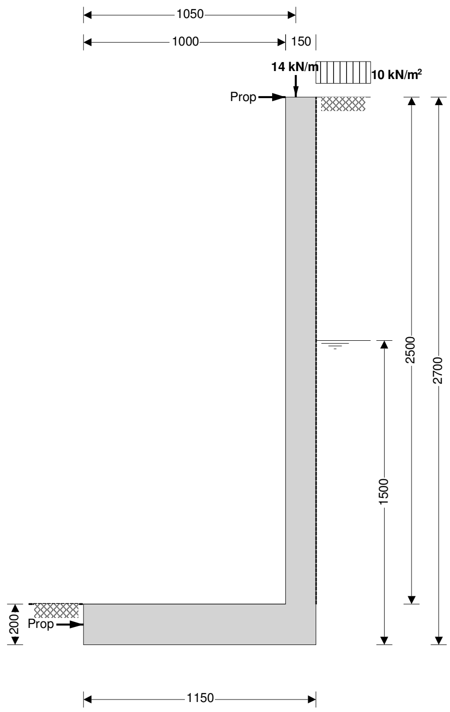
Ground pressure $(91.5/0.8)(1+(6 \times 0.29/0.8))$ = 363 N/mm² — high!

makes no burden
91.5/0.6 = 732 N/mm² — ok   91.5/0.6 = 152.5 N/mm² — check

→ EXISTING WALL IS NOT SATISFACTORY TO ACT AS RETAINING WALL → NEW INTERNAL REQ'D.

RETAINING WALL ANALYSIS (BS 8002:1994)

TEDDS calculation version 1.2.01.06



Wall details

Retaining wall type	**Cantilever propped at both**
Height of retaining wall stem	h_{stem} = **2500** mm
Thickness of wall stem	t_{wall} = **150** mm
Length of toe	l_{toe} = **1000** mm
Length of heel	l_{heel} = **0** mm
Overall length of base	$l_{base} = l_{toe} + l_{heel} + t_{wall}$ = **1150** mm
Thickness of base	t_{base} = **200** mm
Depth of downstand	d_{ds} = **0** mm
Position of downstand	l_{ds} = **700** mm
Thickness of downstand	t_{ds} = **200** mm
Height of retaining wall	$h_{wall} = h_{stem} + t_{base} + d_{ds}$ = **2700** 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	$h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0\ mm)$ = **1300** 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	$h_{eff} = h_{wall} + l_{heel} \times \tan(\beta)$ = **2700** mm

Retained material details

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

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

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

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

Base material details

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 $P_{bearing}$ = **150** 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} = **11.5** kN/m

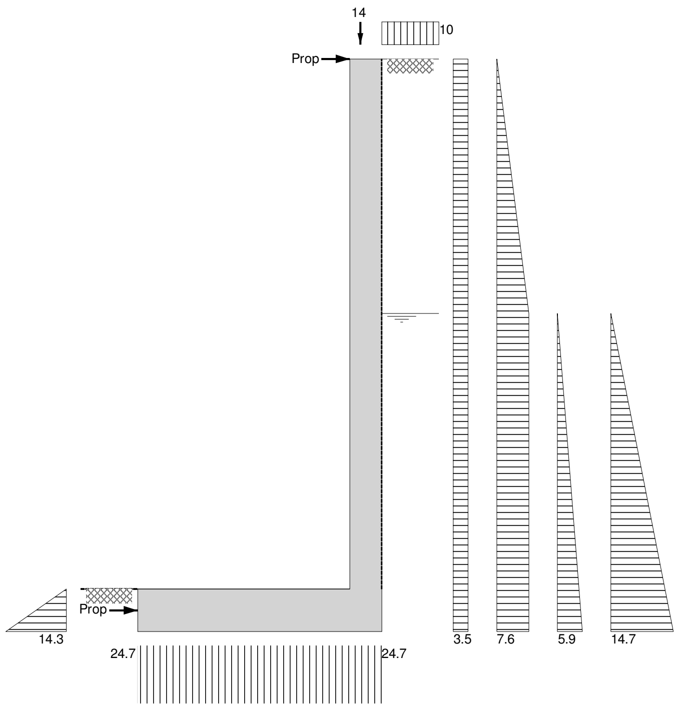
Applied vertical live load on wall W_{live} = **2.6** kN/m

Position of applied vertical load on wall l_{load} = **1050** 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 $w_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall}$ = **8.9** kN/m

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

Applied vertical load $W_v = W_{dead} + W_{live}$ = **14.1** kN/m

Total vertical load $W_{total} = w_{wall} + w_{base} + W_v$ = **28.4** kN/m

Horizontal forces on wall

Surcharge $F_{sur} = K_a \times \cos(90 - \alpha + \delta) \times Surcharge \times h_{eff}$ = **9.4** kN/m

Moist backfill above water table $F_{m\_a} = 0.5 \times K_a \times \cos(90 - \alpha + \delta) \times \gamma_m \times (h_{eff} - h_{water})^2$ = **4.5** kN/m

Moist backfill below water table $F_{m\_b} = K_a \times \cos(90 - \alpha + \delta) \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **11.3** kN/m

Saturated backfill $F_s = 0.5 \times K_a \times \cos(90 - \alpha + \delta) \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **4.4** kN/m

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

Total horizontal load $F_{total} = F_{sur} + F_{m\_a} + F_{m\_b} + F_s + F_{water}$ = **40.8** kN/m

Calculate total propping force

Passive resistance of soil in front of wall $F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **1.4** 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} = **30.7** kN/m

Overturning moments

Surcharge $M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **12.8** kNm/m

Moist backfill above water table $M_{m\_a} = F_{m\_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **8.6** kNm/m

Moist backfill below water table $M_{m\_b} = F_{m\_b} \times (h_{water} - 2 \times d_{ds}) / 2$ = **8.5** kNm/m

Saturated backfill $M_s = F_s \times (h_{water} - 3 \times d_{ds}) / 3$ = **2.2** kNm/m

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

Total overturning moment $M_{ot} = M_{sur} + M_{m\_a} + M_{m\_b} + M_s + M_{water}$ = **37.6** kNm/m

Restoring moments

Wall stem $M_{wall} = w_{wall} \times (l_{toe} + t_{wall} / 2)$ = **9.5** kNm/m

Wall base $M_{base} = w_{base} \times l_{base} / 2$ = **3.1** kNm/m

Design vertical dead load $M_{dead} = W_{dead} \times l_{load}$ = **12.1** kNm/m

Total restoring moment $M_{rest} = M_{wall} + M_{base} + M_{dead}$ = **24.7** kNm/m

Check bearing pressure

Total vertical reaction $R = W_{total}$ = **28.4** kN/m

Distance to reaction $x_{bar} = l_{base} / 2$ = **575** mm

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

Reaction acts within middle third of base

Bearing pressure at toe $p_{toe} = (R / l_{base}) - (6 \times R \times e / l_{base}^2)$ = **24.7** kN/m²

Bearing pressure at heel $p_{heel} = (R / l_{base}) + (6 \times R \times e / l_{base}^2)$ = **24.7** 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

$F_{prop\_top} = (M_{ot} - M_{rest} + R \times l_{base} / 2 - F_{prop} \times t_{base} / 2) / (h_{stem} + t_{base} / 2)$ = **10.050** kN/m

Propping force to base of wall $F_{prop\_base} = F_{prop} - F_{prop\_top}$ = **20.602** 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 $w_{wall\_f} = \gamma_{f\_d} \times h_{stem} \times t_{wall} \times \gamma_{wall}$ = **12.4** kN/m

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

Applied vertical load $W_{v\_f} = \gamma_{f\_d} \times W_{dead} + \gamma_{f\_l} \times W_{live}$ = **20.3** kN/m

Total vertical load $W_{total\_f} = w_{wall\_f} + w_{base\_f} + W_{v\_f}$ = **40.2** kN/m

Factored horizontal at-rest forces on wall

Surcharge $F_{sur\_f} = \gamma_{f\_l} \times K_0 \times Surcharge \times h_{eff}$ = **25.5** kN/m

Moist backfill above water table $F_{m\_a\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2$ = **10.7** kN/m

Moist backfill below water table $F_{m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **26.8** kN/m

Saturated backfill $F_{s\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **10.4** 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 $F_{total\_f} = F_{sur\_f} + F_{m\_a\_f} + F_{m\_b\_f} + F_{s\_f} + F_{water\_f}$ = **88.8** kN/m

Calculate total propping force

Passive resistance of soil in front of wall $F_{p\_f} = \gamma_{f\_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **2** 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} = **74.7** kN/m

Factored overturning moments

Surcharge $M_{sur\_f} = F_{sur\_f} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **34.4** kNm/m

Moist backfill above water table $M_{m\_a\_f} = F_{m\_a\_f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **20.3** kNm/m

Moist backfill below water table $M_{m\_b\_f} = F_{m\_b\_f} \times (h_{water} - 2 \times d_{ds}) / 2$ = **20.1** kNm/m

Saturated backfill $M_{s\_f} = F_{s\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **5.2** kNm/m

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

Total overturning moment $M_{ot\_f} = M_{sur\_f} + M_{m\_a\_f} + M_{m\_b\_f} + M_{s\_f} + M_{water\_f}$ = **87.8** kNm/m

Restoring moments

Wall stem $M_{wall\_f} = w_{wall\_f} \times (l_{toe} + t_{wall} / 2)$ = **13.3** kNm/m

Wall base $M_{base\_f} = w_{base\_f} \times l_{base} / 2$ = **4.4** kNm/m

Design vertical load $M_{v\_f} = W_{v\_f} \times l_{load}$ = **21.3** kNm/m

Total restoring moment $M_{rest\_f} = M_{wall\_f} + M_{base\_f} + M_{v\_f}$ = **39** kNm/m

Factored bearing pressure

Total vertical reaction $R_f = W_{total\_f}$ = **40.2** kN/m

Distance to reaction $x_{bar\_f} = l_{base} / 2$ = **575** 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 $p_{toe\_f} = (R_f / l_{base}) - (6 \times R_f \times e_f / l_{base}^2)$ = **35** kN/m²

Bearing pressure at heel $p_{heel\_f} = (R_f / l_{base}) + (6 \times R_f \times e_f / l_{base}^2)$ = **35** 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 $p_{stem\_toe\_f} = \max(p_{toe\_f} - (rate \times l_{toe}), 0 \text{ kN/m}^2)$ = **35** kN/m²

Bearing pressure at mid stem $p_{stem\_mid\_f} = \max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall} / 2)), 0 \text{ kN/m}^2)$ = **35** kN/m²

Bearing pressure at stem / heel $p_{stem\_heel\_f} = \max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall})), 0 \text{ kN/m}^2) = \mathbf{35}$ kN/m^2

Calculate propping forces to top and base of wall

Propping force to top of wall

$F_{prop\_top\_f} = (M_{ot\_f} - M_{rest\_f} + R_f \times l_{base} / 2 - F_{prop\_f} \times t_{base} / 2) / (h_{stem} + t_{base} / 2) = \mathbf{24.796}$ kN/m

Propping force to base of wall $F_{prop\_base\_f} = F_{prop\_f} - F_{prop\_top\_f} = \mathbf{49.873}$ kN/m

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

Material properties

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

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

Base details

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

Cover to reinforcement in toe $c_{toe} = \mathbf{30}$ mm

Calculate shear for toe design

Shear from bearing pressure $V_{toe\_bear} = (p_{toe\_f} + p_{stem\_toe\_f}) \times l_{toe} / 2 = \mathbf{35}$ kN/m

Shear from weight of base $V_{toe\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{toe} \times t_{base} = \mathbf{6.6}$ kN/m

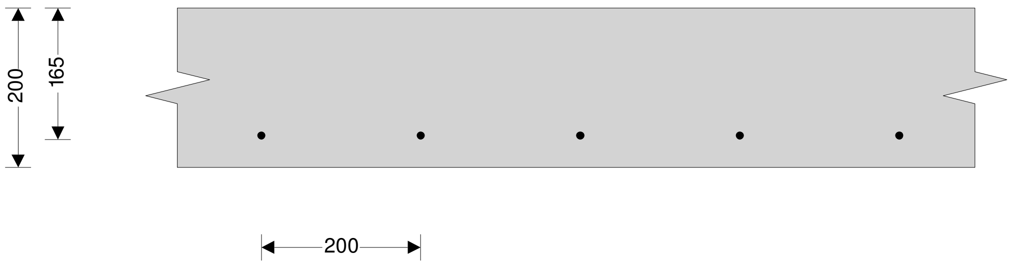
Total shear for toe design $V_{toe} = V_{toe\_bear} - V_{toe\_wt\_base} = \mathbf{28.4}$ kN/m

Calculate moment for toe design

Moment from bearing pressure $M_{toe\_bear} = (2 \times p_{toe\_f} + p_{stem\_mid\_f}) \times (l_{toe} + t_{wall} / 2)^2 / 6 = \mathbf{20.2}$ kNm/m

Moment from weight of base $M_{toe\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2 / 2) = \mathbf{3.8}$ kNm/m

Total moment for toe design $M_{toe} = M_{toe\_bear} - M_{toe\_wt\_base} = \mathbf{16.4}$ kNm/m



Check toe in bending

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

Depth of reinforcement $d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2) = \mathbf{165.0}$ mm

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

Compression reinforcement is not required

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

$z_{toe} = \mathbf{157}$ mm

Area of tension reinforcement required $A_{s\_toe\_des} = M_{toe} / (0.87 \times f_y \times z_{toe}) = \mathbf{241}$ mm^2/m

Minimum area of tension reinforcement $A_{s\_toe\_min} = k \times b \times t_{base} = \mathbf{260}$ mm^2/m

Area of tension reinforcement required $A_{s\_toe\_req} = \text{Max}(A_{s\_toe\_des}, A_{s\_toe\_min}) = \mathbf{260}$ mm^2/m

Reinforcement provided **A393 mesh**

Area of reinforcement provided $A_{s\_toe\_prov} = \mathbf{393}$ mm^2/m

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress $v_{toe} = V_{toe} / (b \times d_{toe}) = \mathbf{0.172}$ N/mm^2

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

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress v_{c_toe} = **0.572** 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} = **40** 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} = **30** mm

Cover to reinforcement in wall c_{wall} = **30** mm

Factored horizontal at-rest forces on stem

Surcharge $F_{s\_sur\_f} = \gamma_{f\_l} \times K_0 \times \text{Surcharge} \times (h_{eff} - t_{base} - d_{ds})$ = **23.6** kN/m

Moist backfill above water table $F_{s\_m\_a\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2$ = **10.7** kN/m

Moist backfill below water table $F_{s\_m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat}) \times h_{sat}$ = **23.2** kN/m

Saturated backfill $F_{s\_s\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{sat}^2$ = **7.8** kN/m

Water $F_{s\_water\_f} = 0.5 \times \gamma_{f\_e} \times \gamma_{water} \times h_{sat}^2$ = **11.6** kN/m

Calculate shear for stem design

Surcharge $V_{s\_sur\_f} = 5 \times F_{s\_sur\_f} / 8$ = **14.8** kN/m

Moist backfill above water table $V_{s\_m\_a\_f} = F_{s\_m\_a\_f} \times b_l \times ((5 \times L^2) - b_l^2) / (5 \times L^3)$ = **4.7** kN/m

Moist backfill below water table $V_{s\_m\_b\_f} = F_{s\_m\_b\_f} \times (8 - (n^2 \times (4 - n))) / 8$ = **20.3** kN/m

Saturated backfill $V_{s\_s\_f} = F_{s\_s\_f} \times (1 - (a_l^2 \times ((5 \times L) - a_l) / (20 \times L^3)))$ = **7.3** kN/m

Water $V_{s\_water\_f} = F_{s\_water\_f} \times (1 - (a_l^2 \times ((5 \times L) - a_l) / (20 \times L^3)))$ = **10.9** kN/m

Total shear for stem design $V_{stem} = V_{s\_sur\_f} + V_{s\_m\_a\_f} + V_{s\_m\_b\_f} + V_{s\_s\_f} + V_{s\_water\_f}$ = **57.9** kN/m

Calculate moment for stem design

Surcharge $M_{s\_sur} = F_{s\_sur\_f} \times L / 8$ = **7.7** kNm/m

Moist backfill above water table $M_{s\_m\_a} = F_{s\_m\_a\_f} \times b_l \times ((5 \times L^2) - (3 \times b_l^2)) / (15 \times L^2)$ = **3.7** kNm/m

Moist backfill below water table $M_{s\_m\_b} = F_{s\_m\_b\_f} \times a_l \times (2 - n)^2 / 8$ = **8.7** kNm/m

Saturated backfill $M_{s\_s} = F_{s\_s\_f} \times a_l \times ((3 \times a_l^2) - (15 \times a_l \times L) + (20 \times L^2)) / (60 \times L^2)$ = **2.3** kNm/m

Water $M_{s\_water} = F_{s\_water\_f} \times a_l \times ((3 \times a_l^2) - (15 \times a_l \times L) + (20 \times L^2)) / (60 \times L^2)$ = **3.5** kNm/m

Total moment for stem design $M_{stem} = M_{s\_sur} + M_{s\_m\_a} + M_{s\_m\_b} + M_{s\_s} + M_{s\_water}$ = **25.9** kNm/m

Calculate moment for wall design

Surcharge $M_{w\_sur} = 9 \times F_{s\_sur\_f} \times L / 128$ = **4.3** kNm/m

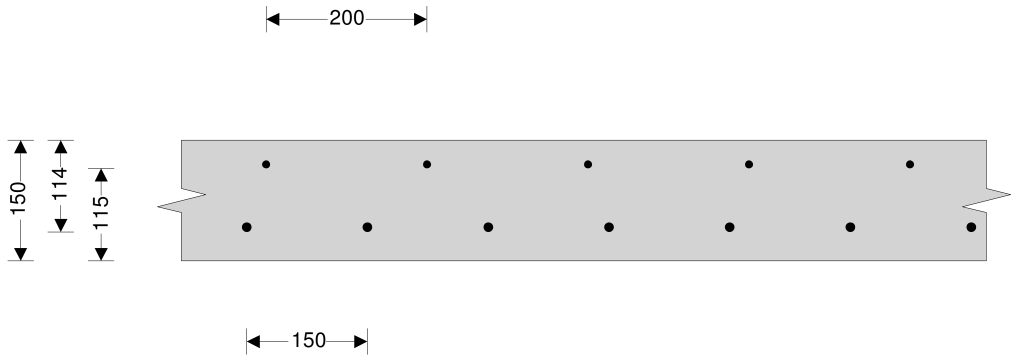
Moist backfill above water table $M_{w\_m\_a} = F_{s\_m\_a\_f} \times 0.577 \times b_l \times [(b_l^3 + 5 \times a_l \times L^2) / (5 \times L^3) - 0.577^2/3]$ = **3.3** kNm/m

Moist backfill below water table $M_{w\_m\_b} = F_{s\_m\_b\_f} \times a_l \times [((8 - n^2 \times (4 - n))^2 / 16) - 4 + n \times (4 - n)] / 8$ = **3.7** kNm/m

Saturated backfill $M_{w\_s} = F_{s\_s\_f} \times [a_l^2 \times x \times ((5 \times L) - a_l) / (20 \times L^3) - (x - b_l)^3 / (3 \times a_l^2)]$ = **0.7** kNm/m

Water $M_{w\_water} = F_{s\_water\_f} \times [a_l^2 \times x \times ((5 \times L) - a_l) / (20 \times L^3) - (x - b_l)^3 / (3 \times a_l^2)]$ = **1.1** kNm/m

Total moment for wall design $M_{wall} = M_{w\_sur} + M_{w\_m\_a} + M_{w\_m\_b} + M_{w\_s} + M_{w\_water}$ = **13.2** kNm/m



Check wall stem in bending

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

Depth of reinforcement $d_{stem} = t_{wall} - c_{stem} - (\phi_{stem} / 2)$ = **114.0** mm

Constant $K_{stem} = M_{stem} / (b \times d_{stem}^2 \times f_{cu})$ = **0.050**

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} = **107** mm

Area of tension reinforcement required $A_{s\_stem\_des} = M_{stem} / (0.87 \times f_y \times z_{stem})$ = **554** mm²/m

Minimum area of tension reinforcement $A_{s\_stem\_min} = k \times b \times t_{wall}$ = **195** mm²/m

Area of tension reinforcement required $A_{s\_stem\_req} = \mathrm{Max}(A_{s\_stem\_des}, A_{s\_stem\_min})$ = **554** mm²/m

Reinforcement provided **12 mm dia.bars @ 150 mm centres**

Area of reinforcement provided $A_{s\_stem\_prov}$ = **754** mm²/m

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress $v_{stem} = V_{stem} / (b \times d_{stem})$ = **0.508** N/mm²

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

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress v_{c_stem} = **0.881** N/mm²

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

Check mid height of wall in bending

Depth of reinforcement $d_{wall} = t_{wall} - c_{wall} - (\phi_{wall} / 2)$ = **115.0** mm

Constant $K_{wall} = M_{wall} / (b \times d_{wall}^2 \times f_{cu})$ = **0.025**

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} = **109** mm

Area of tension reinforcement required $A_{s\_wall\_des} = M_{wall} / (0.87 \times f_y \times z_{wall})$ = **277** mm²/m

Minimum area of tension reinforcement $A_{s\_wall\_min} = k \times b \times t_{wall}$ = **195** mm²/m

Area of tension reinforcement required $A_{s\_wall\_req} = \mathrm{Max}(A_{s\_wall\_des}, A_{s\_wall\_min})$ = **277** mm²/m

Reinforcement provided **A393 mesh**

Area of reinforcement provided $A_{s\_wall\_prov}$ = **393** mm²/m

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

Check retaining wall deflection

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

Design service stress $f_s = 2 \times f_y \times A_{s\_stem\_req} / (3 \times A_{s\_stem\_prov})$ = **245.1** N/mm²

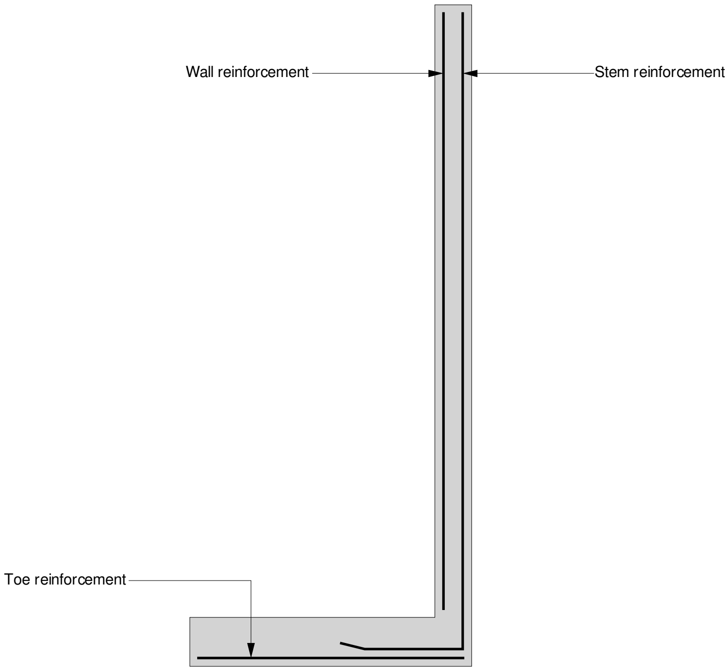
Modification factor $factor_{tens} = min(0.55 + (477\ N/mm^2 - f_s)/(120 \times (0.9\ N/mm^2 + (M_{stem}/(b \times d_{stem}^2)))),2)$ = **1.22**

Maximum span/effective depth ratio $ratio_{max} = ratio_{bas} \times factor_{tens}$ = **24.37**

Actual span/effective depth ratio $ratio_{act} = h_{stem} / d_{stem}$ = **21.93**

PASS - Span to depth ratio is acceptable

Indicative retaining wall reinforcement diagram

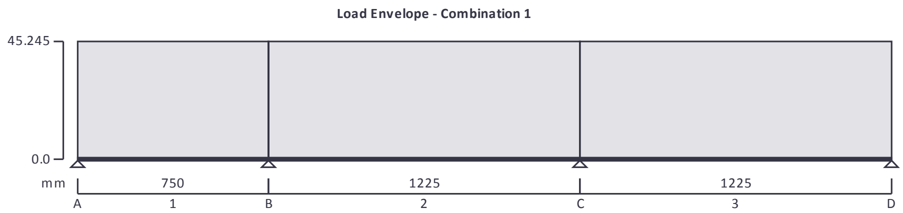


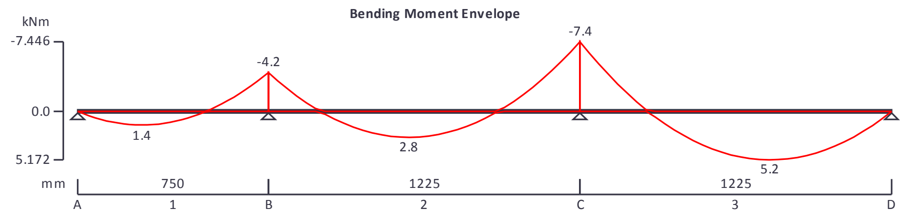
Toe mesh - A393 - (393 mm^2/m)
Wall mesh - A393 - (393 mm^2/m)
Stem bars - 12 mm dia.@ 150 mm centres - (754 mm^2/m)

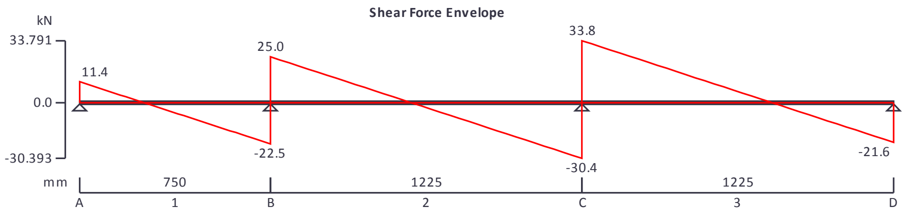
STEEL BEAM ANALYSIS & DESIGN (BS5950)

In accordance with BS5950-1:2000 incorporating Corrigendum No.1

TEDDS calculation version 3.0.07







Support conditions

Support A	Vertically restrained
	Rotationally free
Support B	Vertically restrained
	Rotationally free
Support C	Vertically restrained
	Rotationally free
Support D	Vertically restrained
	Rotationally free

Applied loading

Beam loads	Dead full UDL 15 kN/m
	Imposed full UDL 15 kN/m
	Dead self weight of beam × 1

Load combinations

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

	Support B	Dead × 1.40
		Imposed × 1.60
		Dead × 1.40
		Imposed × 1.60
	Support C	Dead × 1.40
		Imposed × 1.60
		Dead × 1.40
		Imposed × 1.60
	Support D	Dead × 1.40
		Imposed × 1.60

Analysis results

Maximum moment	M_{max} = **5.2** kNm	M_{min} = **-7.4** kNm
Maximum moment span 1	M_{s1_max} = **1.4** kNm	M_{s1_min} = **-4.2** kNm
Maximum moment span 2	M_{s2_max} = **2.8** kNm	M_{s2_min} = **-7.4** kNm
Maximum moment span 3	M_{s3_max} = **5.2** kNm	M_{s3_min} = **-7.4** kNm
Maximum shear	V_{max} = **33.8** kN	V_{min} = **-30.4** kN
Maximum shear span 1	V_{s1_max} = **11.4** kN	V_{s1_min} = **-22.5** kN
Maximum shear span 2	V_{s2_max} = **25** kN	V_{s2_min} = **-30.4** kN
Maximum shear span 3	V_{s3_max} = **33.8** kN	V_{s3_min} = **-21.6** kN
Deflection	δ_{max} = **0.1** mm	δ_{min} = **0** mm
Deflection span 1	δ_{s1_max} = **0** mm	δ_{s1_min} = **0** mm
Deflection span 2	δ_{s2_max} = **0** mm	δ_{s2_min} = **0** mm
Deflection span 3	δ_{s3_max} = **0.1** mm	δ_{s3_min} = **0** mm
Maximum reaction at support A	R_{A_max} = **11.4** kN	R_{A_min} = **11.4** kN
Unfactored dead load reaction at support A	R_{A_Dead} = **3.8** kN	
Unfactored imposed load reaction at support A	$R_{A\_Imposed}$ = **3.8** kN	
Maximum reaction at support B	R_{B_max} = **47.6** kN	R_{B_min} = **47.6** kN
Unfactored dead load reaction at support B	R_{B_Dead} = **15.9** kN	
Unfactored imposed load reaction at support B	$R_{B\_Imposed}$ = **15.8** kN	
Maximum reaction at support C	R_{C_max} = **64.2** kN	R_{C_min} = **64.2** kN
Unfactored dead load reaction at support C	R_{C_Dead} = **21.5** kN	
Unfactored imposed load reaction at support C	$R_{C\_Imposed}$ = **21.3** kN	
Maximum reaction at support D	R_{D_max} = **21.6** kN	R_{D_min} = **21.6** kN
Unfactored dead load reaction at support D	R_{D_Dead} = **7.3** kN	
Unfactored imposed load reaction at support D	$R_{D\_Imposed}$ = **7.2** kN	

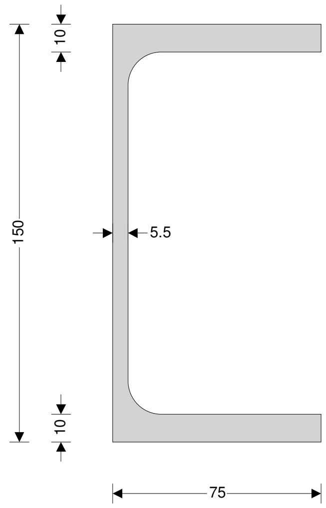
Section details

Section type	**UKPFC 150x75x18 (Tata Steel Advance)**
Steel grade	**S275**

From table 9: Design strength p_y

Thickness of element	max(T, t) = **10.0** mm
Design strength	p_y = **275** N/mm^2
Modulus of elasticity	E = **205000** N/mm^2

Tekla Tedds Conisbee 1-5 Offord Street London N1 1DH	Project 56 Dartmouth Park Road				Job no. 180447	
	Calcs for Whaling beam				Start page no./Revision 3	
	Calcs by HH	Calcs date 07/11/2018	Checked by	Checked date	Approved by	Approved date



Lateral restraint

Span 1 has full lateral restraint

Span 2 has full lateral restraint

Span 3 has full lateral restraint

Effective length factors

Effective length factor in major axis K_x = **1.00**

Effective length factor in minor axis K_y = **1.00**

Effective length factor for lateral-torsional buckling $K_{LT.A}$ = **1.00**

$K_{LT.B}$ = **1.00**

$K_{LT.C}$ = **1.00**

$K_{LT.D}$ = **1.00**

Classification of cross sections - Section 3.5

$\varepsilon = \sqrt{[275 \text{ N/mm}^2 / p_y]}$ = **1.00**

Internal compression parts - Table 11

Depth of section d = **106** mm

$d / t = 19.3 \times \varepsilon <= 80 \times \varepsilon$ Class 1 plastic

Outstand flanges - Table 11

Width of section b = B = **75** mm

$b / T = 7.5 \times \varepsilon <= 9 \times \varepsilon$ Class 1 plastic

Section is class 1 plastic

Shear capacity - Section 4.2.3

Design shear force $F_v = \max(\text{abs}(V_{max}), \text{abs}(V_{min}))$ = **33.8** kN

$d / t < 70 \times \varepsilon$

Web does not need to be checked for shear buckling

Shear area $A_v = t \times D$ = **825** mm²

Design shear resistance $P_v = 0.6 \times p_y \times A_v$ = **136.1** kN

PASS - Design shear resistance exceeds design shear force

Moment capacity at span 2 - Section 4.2.5

Design bending moment $M = \max(\text{abs}(M_{s2\_max}), \text{abs}(M_{s2\_min}))$ = **7.4** kNm

Moment capacity low shear - cl.4.2.5.2 $M_c = \min(p_y \times S_{xx}, 1.5 \times p_y \times Z_{xx})$ = **36.3** kNm

PASS - Moment capacity exceeds design bending moment

Check vertical deflection - Section 2.5.2

Consider deflection due to imposed loads

Limiting deflection $\delta_{lim} = L_{s3} / 360 =$ **3.403** mm

Maximum deflection span 3 $\delta = max(abs(\delta_{max}), abs(\delta_{min})) =$ **0.121** mm

PASS - Maximum deflection does not exceed deflection limit

Tekla Tedds Conisbee 1-5 Offord Street London N1 1DH	Project 56 Dartmouth Park Road				Job no. 180447	
	Calcs for Props				Start page no./Revision 1	
	Calcs by HH	Calcs date 07/11/2018	Checked by	Checked date	Approved by	Approved date

STEEL MEMBER DESIGN (BS5950)

In accordance with BS5950-1:2000 incorporating Corrigendum No.1

TEDDS calculation version 3.0.07

Section details

Section type **UC 152x152x23 (BS4-1)**

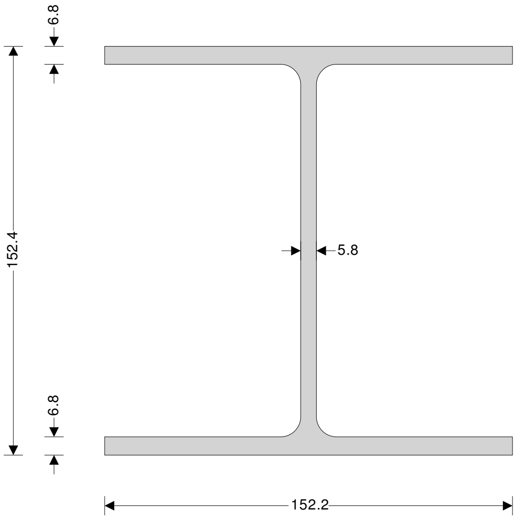
Steel grade **S275**

From table 9: Design strength p_y

Thickness of element max(T, t) = **6.8** mm

Design strength p_y = **275** N/mm²

Modulus of elasticity E = **205000** N/mm²



Lateral restraint

Distance between major axis restraints L_x = **3900** mm

Distance between minor axis restraints L_y = **0** mm

Effective length factors

Effective length factor in major axis K_x = **1.00**

Effective length factor in minor axis K_y = **1.00**

Effective length factor for lateral-torsional buckling K_{LT} = **1.00**

Classification of cross sections - Section 3.5

$\varepsilon = \sqrt{[275 \text{ N/mm}^2 / p_y]}$ = **1.00**

Internal compression parts - Table 11

Depth of section d = **123.6** mm

Stress ratios $r1 = \min(F_c / (d \times t \times p_{yw}), 1)$ = **0.457**

$r2 = F_c / (A \times p_{yw})$ = **0.112**

$d / t = 21.3 \times \varepsilon <= \max(80 \times \varepsilon / (1 + r1), 40 \times \varepsilon)$ Class 1 plastic

Outstand flanges - Table 11

Width of section b = B / 2 = **76.1** mm

$b / T = 11.2 \times \varepsilon <= 15 \times \varepsilon$ Class 3 semi-compact

Section is class 3 semi-compact

Compression members - Section 4.7

Design compression force F_c = **90** kN

Effective length for major (x-x) axis buckling - Section 4.7.3

Effective length for buckling $L_{Ex} = L_x \times K_x =$ **3900** mm

Slenderness ratio - cl.4.7.2 $\lambda_x = L_{Ex} / r_{xx} =$ **59.659**

Compressive strength - Section 4.7.5

Limiting slenderness $\lambda_0 = 0.2 \times (\pi^2 \times E / p_y)^{0.5} =$ **17.155**

Strut curve - Table 23 b

Robertson constant $\alpha_x =$ **3.5**

Perry factor $\eta_x = \alpha_x \times (\lambda_x - \lambda_0) / 1000 =$ **0.149**

Euler stress $p_{Ex} = \pi^2 \times E / \lambda_x^2 =$ **568.5** N/mm^2

$\phi_x = (p_y + (\eta_x + 1) \times p_{Ex}) / 2 =$ **464** N/mm^2

Compressive strength - Annex C.1 $p_{cx} = p_{Ex} \times p_y / (\phi_x + (\phi_x^2 - p_{Ex} \times p_y)^{0.5}) =$ **221.2** N/mm^2

Compression resistance - Section 4.7.4

Compression resistance - cl.4.7.4 $P_{cx} = A \times p_{cx} =$ **646.8** kN

PASS - Compression resistance exceeds design compression force