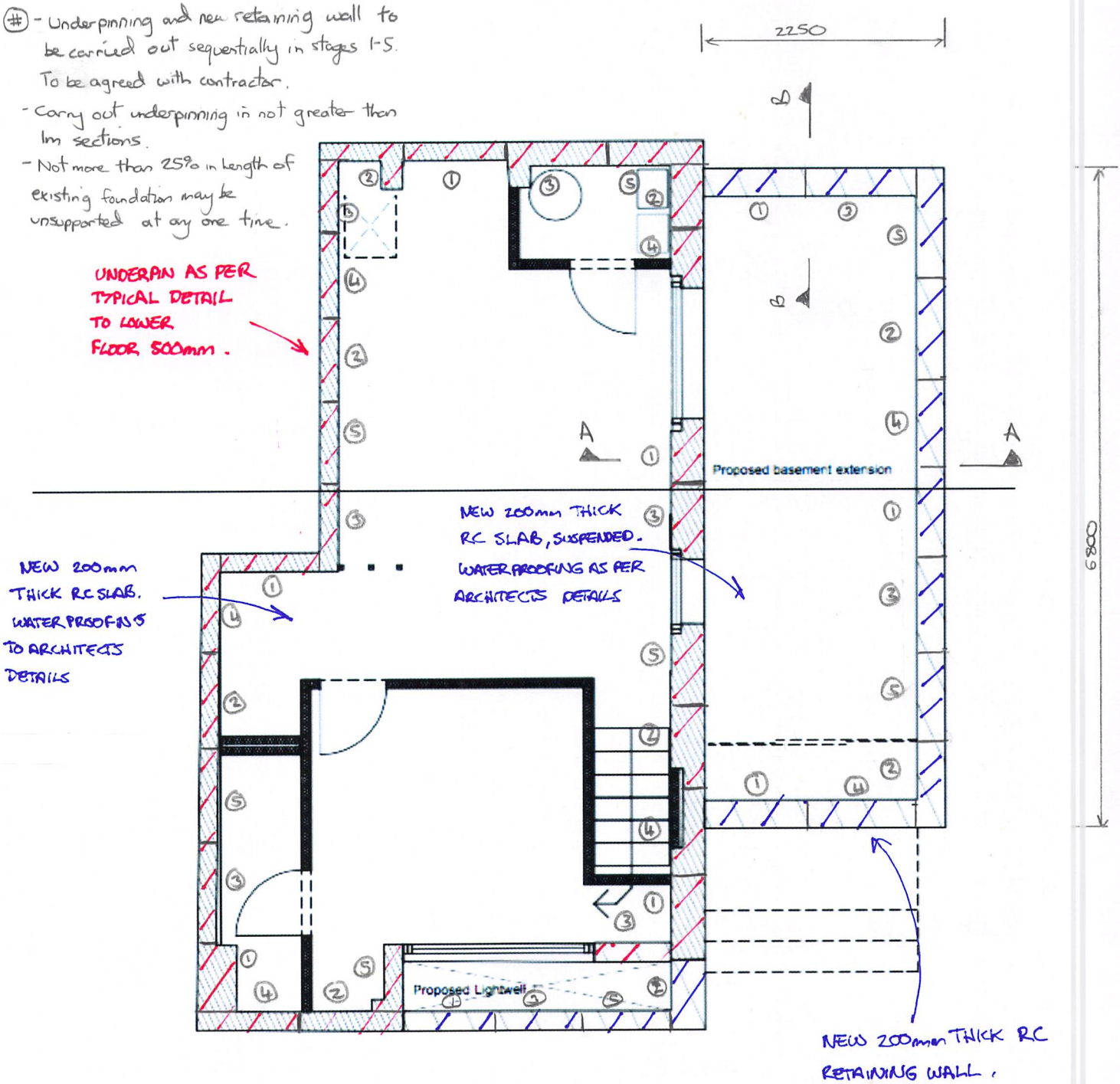
Appendix F: Underpinning and retaining wall information

This section includes:

- Typical underpinning and retaining wall details
- Proposed construction methodologies
- Typical structural calculations for basement extension retaining wall

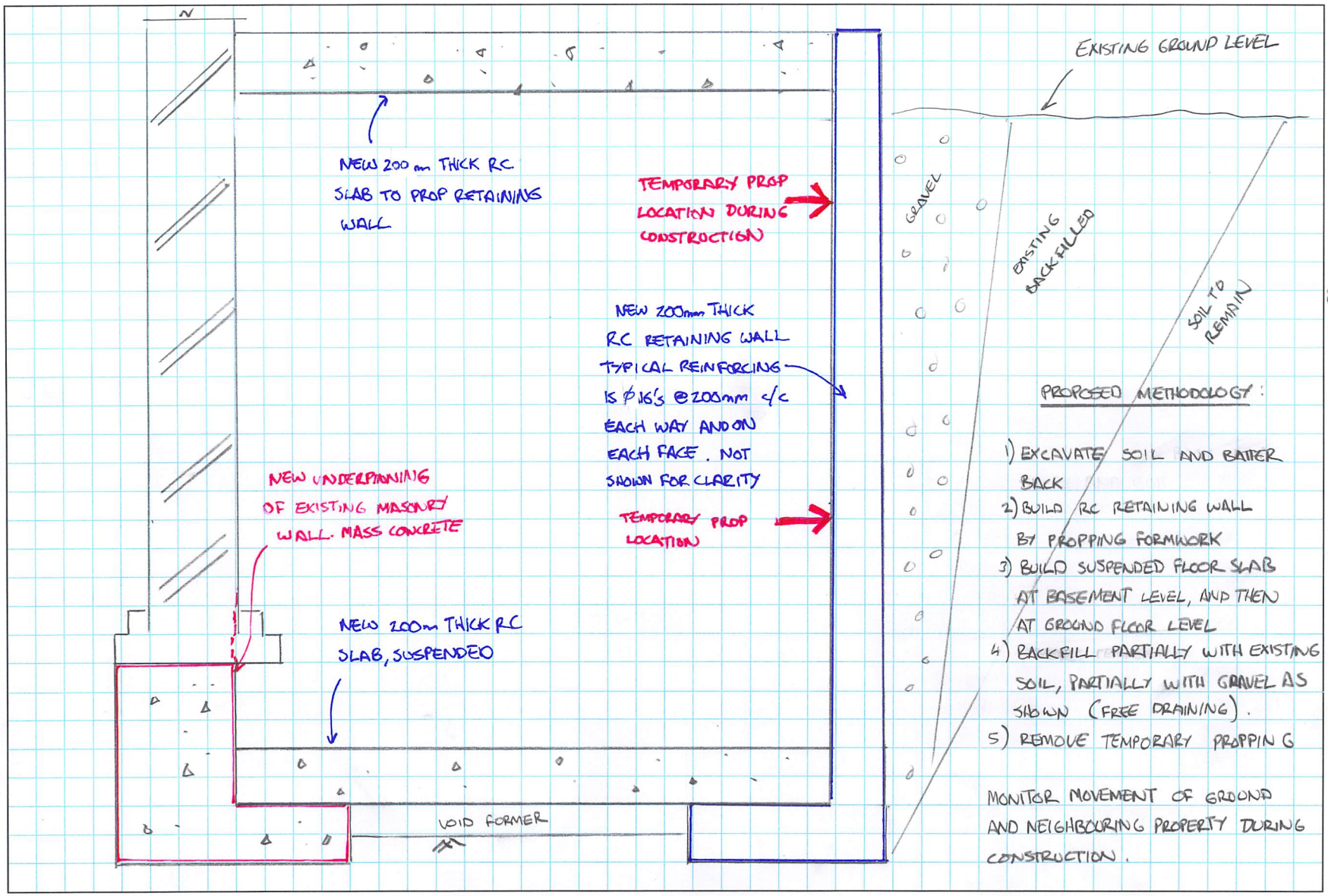
(#) - Underpinning and new retaining wall to be carried out sequentially in stages 1-5. To be agreed with contractor.
- Carry out underpinning in not greater than 1m sections.
- Not more than 25% in length of existing foundation may be unsupported at any one time.



BASEMENT PLAN

NTS

MOMENTUM
59 CROFTDOWN ROAD
RETAINING WALL DESIGN - PLANS
2702/SK0
22/12/2016 BR



SECTION A-A
1:20

Project: 59 Crofton Road

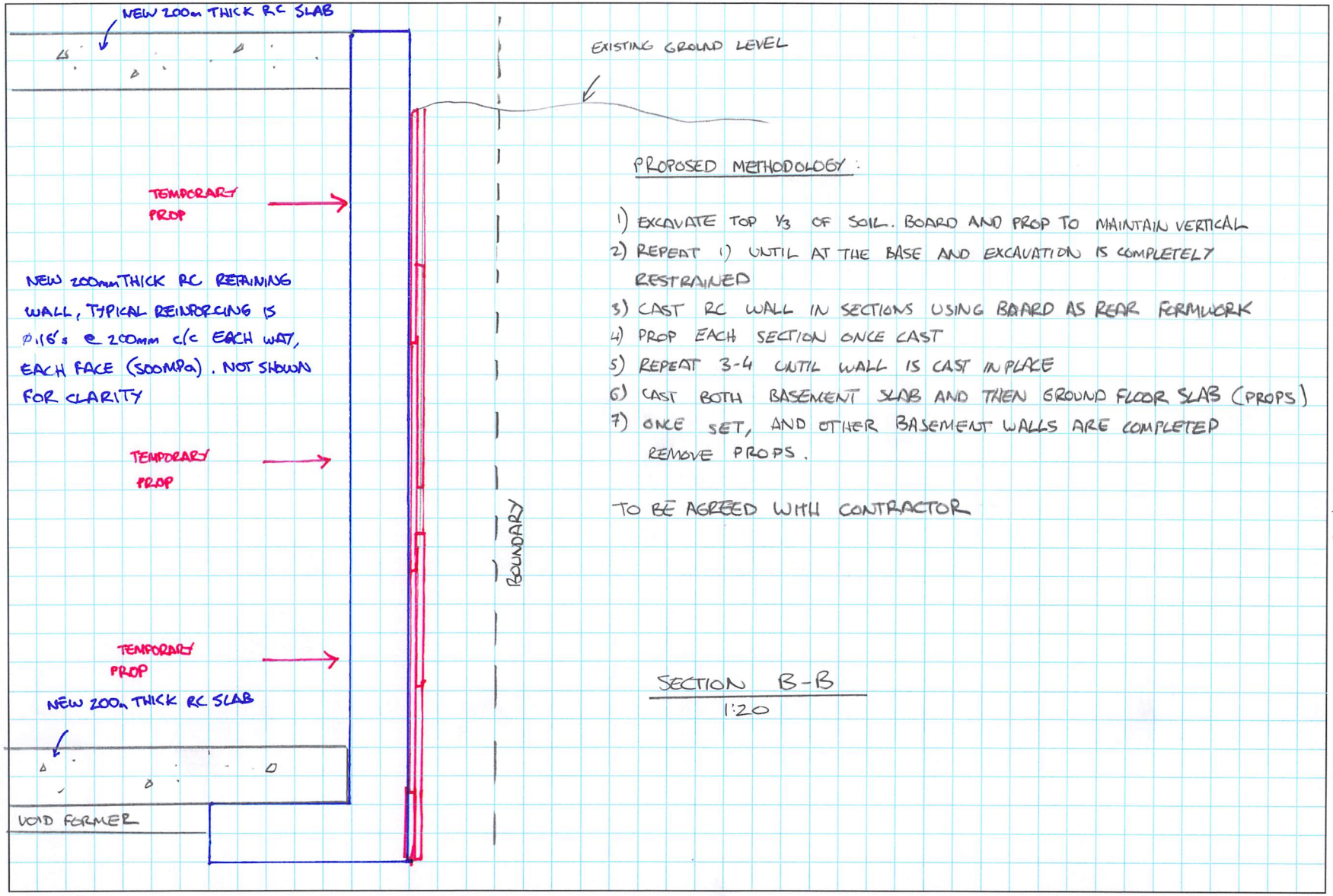
Title: RETAINING WALL DESIGN - SECTION A-A

Date: 22/12/16

By: BR

Reference: 2702

MOMENTUM
structural engineers



PROPOSED METHODOLOGY:

1) EXCAVATE TOP 1/3 OF SOIL. BOARD AND PROP TO MAINTAIN VERTICAL
2) REPEAT 1) UNTIL AT THE BASE AND EXCAVATION IS COMPLETELY RESTRAINED
3) CAST RC WALL IN SECTIONS USING BOARD AS REAR FORMWORK
4) PROP EACH SECTION ONCE CAST
5) REPEAT 3-4 UNTIL WALL IS CAST IN PLACE
6) CAST BOTH BASEMENT SLAB AND THEN GROUND FLOOR SLAB (PROPS)
7) ONCE SET, AND OTHER BASEMENT WALLS ARE COMPLETED REMOVE PROPS.

TO BE AGREED WITH CONTRACTOR

SECTION B-B
1:20

Project: 59 Croftdown Road

Title: RETAINING WALL DESIGN - SECTION B-B

Date: 22/12/16

By: BR

Reference: 2702

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59 Croftdown Road

Typical structural calculations

22 December 2016. 2702 Rev[00]

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Author
B Ramsay

Issue History

Rev.	Date	Comments
00	22.12.2016	First Issue

Contents

1 Introduction

These calculations are to provide the typical design for the proposed basement extension at 59 Croftdown Road. The proposal is for the existing basement to be lowered by 500mm, with a 2.5m x 6.8m basement extension on the Northern face of the building.

These structural calculations cover:

a) Typical underpinning for the existing structure
b) Typical propped retaining wall design for the new extension.

The below figure identifies the alterations to the existing basement.

Figure 1: Site plan

2 Underpinning design

2.1 Underpinning philosophy

The existing foundations consist of corbeled masonry with a wider concrete crush footing underneath as found in the site investigation.

The proposed underpinning consists of reinforced concrete lowering the existing foundations by 500mm. The same width of footing will be maintained as a minimum therefore maintaining the same scenario typically.

Based on our understanding of the structure, the northern, eastern and southern walls are currently retaining soil with the western wall being a party wall.

The southern, eastern and western walls are all supported by return walls or piers at regular centres. Based on this, the walls are considered to be spanning horizontally typically, with piers and return walls spanning vertically. The 500mm underpinning does not change the existing scenario as effectively a rigid block will be provided at the base to support the existing wall above.

The underpinning will be designed to take the shear load from the piers and return walls to the new foundation level via dowels.

For the northern wall we are removing the soil being retained over the majority of the walls length, and are providing a new retained structure at the new external edge of the basement. Therefore the wall is only required to take vertical loading, which will be adequate by inspection as we will provide the same width of foundation as the existing as a minimum.

3 Typical retaining wall design

Typical retaining wall calculations have been provided using Tedds. Refer to the attached for the calculations. The parameters for the soil have been obtained from the Ground and Water site investigation report.

The retaining wall has been designed as a reinforced concrete propped cantilever. It will be propped at ground floor via the suspended floor slab and at basement level via another suspended floor slab.

The ground floor slab is then restrained by return walls so is required to act as a diaphragm.

90 Walcot St
Bath
BA1 5BG

Project				Job no.	
59 Croftdown Road				2702	
Calcs for				Start page no./Revision	
Rear garden wall				1	
Calcs by	Calcs date	Checked by	Checked date	Approved by	Approved date
BR	22/12/2016				

RETAINING WALL ANALYSIS

In accordance with EN1997-1:2004 incorporating Corrigendum dated February 2009 and the UK National Annex incorporating Corrigendum No.1

Tedds calculation version 2.4.09

Retaining wall details

Stem type	Propped cantilever
Stem height	h_{stem} = **2700** mm
Prop height	h_{prop} = **2700** mm
Stem thickness	t_{stem} = **200** mm
Angle to rear face of stem	α = **90** deg
Stem density	γ_{stem} = **24** kN/m^3
Toe length	l_{toe} = **500** mm
Base thickness	t_{base} = **200** mm
Base density	γ_{base} = **24** kN/m^3
Height of retained soil	h_{ret} = **2500** mm
Angle of soil surface	β = **0** deg
Depth of cover	d_{cover} = **200** mm
Depth of excavation	d_{exc} = **200** mm
Height of water	h_{water} = **2500** mm
Water density	γ_w = **9.8** kN/m^3

Retained soil properties

Soil type	Stiff clay
Moist density	γ_{mr} = **20** kN/m^3
Saturated density	γ_{sr} = **20** kN/m^3
Characteristic effective shear resistance angle	$\phi'_{r.k}$ = **24** deg
Characteristic wall friction angle	$\delta_{r.k}$ = **9** deg

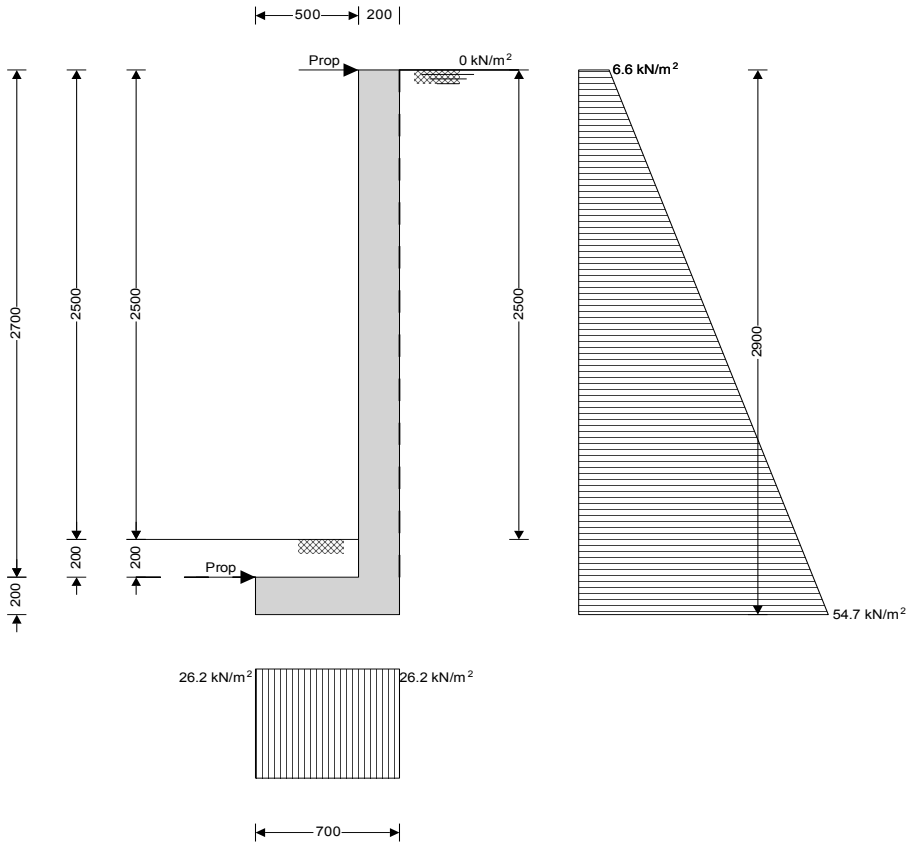
Base soil properties

Soil type	Stiff clay
Moist density	γ_{mb} = **20** kN/m^3
Characteristic effective shear resistance angle	$\phi'_{b.k}$ = **24** deg
Characteristic wall friction angle	$\delta_{b.k}$ = **12** deg
Characteristic base friction angle	$\delta_{bb.k}$ = **16** deg
Presumed bearing capacity	$P_{bearing}$ = **150** kN/m^2

Loading details

Permanent surcharge load	Surcharge$_G$ = **10** kN/m^2

90 Walcot St Bath BA1 5BG	Project 59 Croftdown Road				Job no. 2702	
	Calcs for Rear garden wall				Start page no./Revision 2	
	Calcs by BR	Calcs date 22/12/2016	Checked by	Checked date	Approved by	Approved date



Calculate retaining wall geometry

Base length	$l_{base} = l_{toe} + t_{stem} =$ **700** mm
Saturated soil height	$h_{sat} = h_{water} + d_{cover} =$ **2700** mm
Moist soil height	$h_{moist} = h_{ret} - h_{water} =$ **0** mm
Length of surcharge load	$l_{sur} = l_{heel} =$ **0** mm
- Distance to vertical component	$x_{sur\_v} = l_{base} - l_{heel} / 2 =$ **700** mm
Effective height of wall	$h_{eff} = h_{base} + d_{cover} + h_{ret} =$ **2900** mm
- Distance to horizontal component	$x_{sur\_h} = h_{eff} / 2 =$ **1450** mm
Area of wall stem	$A_{stem} = h_{stem} \times t_{stem} =$ **0.54** m²
- Distance to vertical component	$x_{stem} = l_{toe} + t_{stem} / 2 =$ **600** mm
Area of wall base	$A_{base} = l_{base} \times t_{base} =$ **0.14** m²
- Distance to vertical component	$x_{base} = l_{base} / 2 =$ **350** mm
Area of base soil	$A_{pass} = d_{cover} \times l_{toe} =$ **0.1** m²
- Distance to vertical component	$x_{pass\_v} = l_{base} - (d_{cover} \times l_{toe} \times (l_{base} - l_{toe} / 2)) / A_{pass} =$ **250** mm
- Distance to horizontal component	$x_{pass\_h} = (d_{cover} + h_{base}) / 3 =$ **133** mm

Using Rankine theory

At rest pressure coefficient	$K_0 = 1 - \sin(\phi'_{r.k}) =$ **0.593**
Passive pressure coefficient	$K_P = (1 + \sin(\phi'_{b.k})) / (1 - \sin(\phi'_{b.k})) =$ **2.371**

Bearing pressure check

Vertical forces on wall

Wall stem	$F_{stem} = A_{stem} \times \gamma_{stem} =$ **13** kN/m

Wall base	$F_{base} = A_{base} \times \gamma_{base} =$ **3.4** kN/m
Base soil	$F_{pass\_v} = A_{pass} \times \gamma_{mb} =$ **2** kN/m
Total	$F_{total\_v} = F_{stem} + F_{base} + F_{pass\_v} + F_{water\_v} =$ **18.3** kN/m

Horizontal forces on wall

Surcharge load	$F_{sur\_h} = K_0 \times Surcharge_G \times h_{eff} =$ **17.2** kN/m
Saturated retained soil	$F_{sat\_h} = K_0 \times (\gamma_{sr} - \gamma_w) \times (h_{sat} + h_{base})^2 / 2 =$ **25.4** kN/m
Water	$F_{water\_h} = \gamma_w \times (h_{water} + d_{cover} + h_{base})^2 / 2 =$ **41.3** kN/m
Moist retained soil	$F_{moist\_h} = K_0 \times \gamma_{mr} \times ((h_{eff} - h_{sat} - h_{base})^2 / 2 + (h_{eff} - h_{sat} - h_{base}) \times (h_{sat} + h_{base})) =$ **0** kN/m
Total	$F_{total\_h} = F_{sat\_h} + F_{moist\_h} + F_{water\_h} + F_{sur\_h} =$ **83.9** kN/m

Moments on wall

Wall stem	$M_{stem} = F_{stem} \times x_{stem} =$ **7.8** kNm/m
Wall base	$M_{base} = F_{base} \times x_{base} =$ **1.2** kNm/m
Surcharge load	$M_{sur} = -F_{sur\_h} \times x_{sur\_h} =$ **-24.9** kNm/m
Saturated retained soil	$M_{sat} = -F_{sat\_h} \times x_{sat\_h} =$ **-24.6** kNm/m
Water	$M_{water} = -F_{water\_h} \times x_{water\_h} =$ **-39.9** kNm/m
Moist retained soil	$M_{moist} = -F_{moist\_h} \times x_{moist\_h} =$ **0** kNm/m
Base soil	$M_{pass} = F_{pass\_v} \times x_{pass\_v} =$ **0.5** kNm/m
Total	$M_{total} = M_{stem} + M_{base} + M_{sat} + M_{moist} + M_{pass} + M_{water} + M_{sur} =$ **-79.9** kNm/m

Check bearing pressure

Propping force to stem	$F_{prop\_stem} = \min((F_{total\_v} \times l_{base} / 2 - M_{total}) / (h_{prop} + t_{base}), F_{total\_h}) =$ **29.8** kN/m
Propping force to base	$F_{prop\_base} = F_{total\_h} - F_{prop\_stem} =$ **54.1** kN/m
Moment from propping force	$M_{prop} = F_{prop\_stem} \times (h_{prop} + t_{base}) =$ **86.4** kNm/m
Distance to reaction	$\bar{x} = (M_{total} + M_{prop}) / F_{total\_v} =$ **350** mm
Eccentricity of reaction	$e = \bar{x} - l_{base} / 2 =$ **0** mm
Loaded length of base	$l_{load} = l_{base} =$ **700** mm
Bearing pressure at toe	$q_{toe} = F_{total\_v} / l_{base} =$ **26.2** kN/m^2
Bearing pressure at heel	$q_{heel} = F_{total\_v} / l_{base} =$ **26.2** kN/m^2
Factor of safety	$FoS_{bp} = P_{bearing} / \max(q_{toe}, q_{heel}) =$ **5.731**

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

RETAINING WALL DESIGN

In accordance with EN1992-1-1:2004 incorporating Corrigendum dated January 2008 and the UK National Annex incorporating National Amendment No.1

Tedds calculation version 2.4.09

Concrete details - Table 3.1 - Strength and deformation characteristics for concrete

Concrete strength class	C30/37
Characteristic compressive cylinder strength	$f_{ck} =$ **30** N/mm^2
Characteristic compressive cube strength	$f_{ck,cube} =$ **37** N/mm^2
Mean value of compressive cylinder strength	$f_{cm} = f_{ck} + 8$ N/mm^2 = **38** N/mm^2
Mean value of axial tensile strength	$f_{ctm} = 0.3$ N/mm^2 $\times (f_{ck} / 1$ N/mm$^2)^{2/3} =$ **2.9** N/mm^2
5% fractile of axial tensile strength	$f_{ctk,0.05} = 0.7 \times f_{ctm} =$ **2.0** N/mm^2
Secant modulus of elasticity of concrete	$E_{cm} = 22$ kN/mm^2 $\times (f_{cm} / 10$ N/mm$^2)^{0.3} =$ **32837** N/mm^2
Partial factor for concrete - Table 2.1N	$\gamma_C =$ **1.50**

Compressive strength coefficient - cl.3.1.6(1)	α_{cc} = **0.85**
Design compressive concrete strength - exp.3.15	$f_{cd} = \alpha_{cc} \times f_{ck} / \gamma_C$ = **17.0** N/mm^2
Maximum aggregate size	h_{agg} = **20** mm
Reinforcement details	
Characteristic yield strength of reinforcement	f_{yk} = **500** N/mm^2
Modulus of elasticity of reinforcement	E_s = **200000** N/mm^2
Partial factor for reinforcing steel - Table 2.1N	γ_S = **1.15**
Design yield strength of reinforcement	$f_{yd} = f_{yk} / \gamma_S$ = **435** N/mm^2
Cover to reinforcement	
Front face of stem	c_{sf} = **40** mm
Rear face of stem	c_{sr} = **50** mm
Top face of base	c_{bt} = **50** mm
Bottom face of base	c_{bb} = **75** mm
Check stem design at 1439 mm	
Depth of section	h = **200** mm
Rectangular section in flexure - Section 6.1	
Design bending moment combination 1	M = **16.6** kNm/m
Depth to tension reinforcement	$d = h - c_{sf} - \phi_{sx} - \phi_{sfM} / 2$ = **144** mm
	$K = M / (d^2 \times f_{ck})$ = **0.027**
	K' = **0.207**
	K' > K - No compression reinforcement is required
Lever arm	$z = \min(0.5 + 0.5 \times (1 - 3.53 \times K)^{0.5}, 0.95) \times d$ = **137** mm
Depth of neutral axis	$x = 2.5 \times (d - z)$ = **18** mm
Area of tension reinforcement required	$A_{sfM.req} = M / (f_{yd} \times z)$ = **278** mm^2/m
Tension reinforcement provided	12 dia.bars @ 200 c/c
Area of tension reinforcement provided	$A_{sfM.prov} = \pi \times \phi_{sfM}^2 / (4 \times s_{sfM})$ = **565** mm^2/m
Minimum area of reinforcement - exp.9.1N	$A_{sfM.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d$ = **217** mm^2/m
Maximum area of reinforcement - cl.9.2.1.1(3)	$A_{sfM.max} = 0.04 \times h$ = **8000** mm^2/m
	$\max(A_{sfM.req}, A_{sfM.min}) / A_{sfM.prov}$ = **0.492**
	PASS - Area of reinforcement provided is greater than area of reinforcement required
Crack control - Section 7.3	
Limiting crack width	w_{max} = **0.3** mm
Variable load factor - EN1990 – Table A1.1	ψ_2 = **0.6**
Serviceability bending moment	M_{sls} = **12.3** kNm/m
Tensile stress in reinforcement	$\sigma_s = M_{sls} / (A_{sfM.prov} \times z)$ = **158.5** N/mm^2
Load duration	Long term
Load duration factor	k_t = **0.4**
Effective area of concrete in tension	$A_{c.eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$ = **60667** mm^2/m
Mean value of concrete tensile strength	$f_{ct.eff} = f_{ctm}$ = **2.9** N/mm^2
Reinforcement ratio	$\rho_{p.eff} = A_{sfM.prov} / A_{c.eff}$ = **0.009**
Modular ratio	$\alpha_e = E_s / E_{cm}$ = **6.091**
Bond property coefficient	k_1 = **0.8**
Strain distribution coefficient	k_2 = **0.5**
	k_3 = **3.4**
	k_4 = **0.425**

Maximum crack spacing - exp.7.11	$s_{r.max} = k_3 \times c_{sf} + k_1 \times k_2 \times k_4 \times \phi_{sfM} / \rho_{p.eff}$ = **355** mm
Maximum crack width - exp.7.8	$w_k = s_{r.max} \times \max(\sigma_s - k_t \times (f_{ct.eff} / \rho_{p.eff}) \times (1 + \alpha_e \times \rho_{p.eff}), 0.6 \times \sigma_s) / E_s$
	w_k = **0.169** mm
	w_k / w_{max} = **0.562**
	PASS - Maximum crack width is less than limiting crack width

Check stem design at base of stem

Depth of section	h = **200** mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 1	M = **35.4** kNm/m
Depth to tension reinforcement	$d = h - c_{sr} - \phi_{sr} / 2$ = **142** mm
	$K = M / (d^2 \times f_{ck})$ = **0.058**
	K' = **0.207**
	K' > K - No compression reinforcement is required
Lever arm	$z = \min(0.5 + 0.5 \times (1 - 3.53 \times K)^{0.5}, 0.95) \times d$ = **134** mm
Depth of neutral axis	$x = 2.5 \times (d - z)$ = **19** mm
Area of tension reinforcement required	$A_{sr.req} = M / (f_{yd} \times z)$ = **606** mm²/m
Tension reinforcement provided	16 dia.bars @ 200 c/c
Area of tension reinforcement provided	$A_{sr.prov} = \pi \times \phi_{sr}^2 / (4 \times s_{sr})$ = **1005** mm²/m
Minimum area of reinforcement - exp.9.1N	$A_{sr.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d$ = **214** mm²/m
Maximum area of reinforcement - cl.9.2.1.1(3)	$A_{sr.max} = 0.04 \times h$ = **8000** mm²/m
	$\max(A_{sr.req}, A_{sr.min}) / A_{sr.prov}$ = **0.603**
	PASS - Area of reinforcement provided is greater than area of reinforcement required

Crack control - Section 7.3

Limiting crack width	w_{max} = **0.3** mm
Variable load factor - EN1990 – Table A1.1	ψ_2 = **0.6**
Serviceability bending moment	M_{sls} = **26.2** kNm/m
Tensile stress in reinforcement	$\sigma_s = M_{sls} / (A_{sr.prov} \times z)$ = **194.2** N/mm²
Load duration	Long term
Load duration factor	k_t = **0.4**
Effective area of concrete in tension	$A_{c.eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$ = **60205** mm²/m
Mean value of concrete tensile strength	$f_{ct.eff} = f_{ctm}$ = **2.9** N/mm²
Reinforcement ratio	$\rho_{p.eff} = A_{sr.prov} / A_{c.eff}$ = **0.017**
Modular ratio	$\alpha_e = E_s / E_{cm}$ = **6.091**
Bond property coefficient	k_1 = **0.8**
Strain distribution coefficient	k_2 = **0.5**
	k_3 = **3.4**
	k_4 = **0.425**
Maximum crack spacing - exp.7.11	$s_{r.max} = k_3 \times c_{sr} + k_1 \times k_2 \times k_4 \times \phi_{sr} / \rho_{p.eff}$ = **333** mm
Maximum crack width - exp.7.8	$w_k = s_{r.max} \times \max(\sigma_s - k_t \times (f_{ct.eff} / \rho_{p.eff}) \times (1 + \alpha_e \times \rho_{p.eff}), 0.6 \times \sigma_s) / E_s$
	w_k = **0.196** mm
	w_k / w_{max} = **0.653**
	PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force	V = **75.9** kN/m
	$C_{Rd,c} = 0.18 / \gamma_C$ = **0.120**
	$k = \min(1 + \sqrt{}(200 \text{ mm} / d), 2)$ = **2.000**

Longitudinal reinforcement ratio	$\rho_l = \min(A_{sf.prov} / d, 0.02) =$ **0.007**
	$v_{min} = 0.035\ N^{1/2}/mm \times k^{3/2} \times f_{ck}^{0.5} =$ **0.542** N/mm^2
Design shear resistance - exp.6.2a & 6.2b	$V_{Rd.c} = \max(C_{Rd.c} \times k \times (100\ N^2/mm^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$
	$V_{Rd.c} =$ **94.4** kN/m
	$V / V_{Rd.c} =$ **0.805**
	PASS - Design shear resistance exceeds design shear force

Check stem design at prop

Depth of section	h = **200** mm

Rectangular section in shear - Section 6.2

Design shear force	V = **23.7** kN/m
	$C_{Rd,c} = 0.18 / \gamma_C =$ **0.120**
	$k = \min(1 + \sqrt{(200\ mm / d)}, 2) =$ **2.000**
Longitudinal reinforcement ratio	$\rho_l = \min(A_{sf1.prov} / d, 0.02) =$ **0.004**
	$v_{min} = 0.035\ N^{1/2}/mm \times k^{3/2} \times f_{ck}^{0.5} =$ **0.542** N/mm^2
Design shear resistance - exp.6.2a & 6.2b	$V_{Rd.c} = \max(C_{Rd.c} \times k \times (100\ N^2/mm^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$
	$V_{Rd.c} =$ **77.9** kN/m
	$V / V_{Rd.c} =$ **0.304**
	PASS - Design shear resistance exceeds design shear force

Horizontal reinforcement parallel to face of stem - Section 9.6

Minimum area of reinforcement – cl.9.6.3(1)	$A_{sx.req} = \max(0.25 \times A_{sr.prov}, 0.001 \times t_{stem}) =$ **251** mm^2/m
Maximum spacing of reinforcement – cl.9.6.3(2)	$s_{sx\_max} =$ **400** mm
Transverse reinforcement provided	10 dia.bars @ 200 c/c
Area of transverse reinforcement provided	$A_{sx.prov} = \pi \times \phi_{sx}^2 / (4 \times s_{sx}) =$ **393** mm^2/m
	PASS - Area of reinforcement provided is greater than area of reinforcement required

Check base design at toe

Depth of section	h = **200** mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 1	M = **2.9** kNm/m
Depth to tension reinforcement	$d = h - c_{bb} - \phi_{bb} / 2 =$ **119** mm
	$K = M / (d^2 \times f_{ck}) =$ **0.007**
	K' = **0.207**
	K' > K - No compression reinforcement is required
Lever arm	$z = \min(0.5 + 0.5 \times (1 - 3.53 \times K)^{0.5}, 0.95) \times d =$ **113** mm
Depth of neutral axis	$x = 2.5 \times (d - z) =$ **15** mm
Area of tension reinforcement required	$A_{bb.req} = M / (f_{yd} \times z) =$ **60** mm^2/m
Tension reinforcement provided	12 dia.bars @ 200 c/c
Area of tension reinforcement provided	$A_{bb.prov} = \pi \times \phi_{bb}^2 / (4 \times s_{bb}) =$ **565** mm^2/m
Minimum area of reinforcement - exp.9.1N	$A_{bb.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d =$ **179** mm^2/m
Maximum area of reinforcement - cl.9.2.1.1(3)	$A_{bb.max} = 0.04 \times h =$ **8000** mm^2/m
	$\max(A_{bb.req}, A_{bb.min}) / A_{bb.prov} =$ **0.317**
	PASS - Area of reinforcement provided is greater than area of reinforcement required

Crack control - Section 7.3

Limiting crack width	$w_{max} =$ **0.3** mm
Variable load factor - EN1990 – Table A1.1	$\psi_2 =$ **0.6**
Serviceability bending moment	$M_{sls} =$ **2.2** kNm/m

Tensile stress in reinforcement	$\sigma_s = M_{sls} / (A_{bb.prov} \times z)$ = **34** N/mm^2
Load duration	Long term
Load duration factor	k_t = **0.4**
Effective area of concrete in tension	$A_{c.eff}$ = min(2.5 × (h - d), (h – x) / 3, h / 2) = **61708** mm^2/m
Mean value of concrete tensile strength	$f_{ct.eff} = f_{ctm}$ = **2.9** N/mm^2
Reinforcement ratio	$\rho_{p.eff} = A_{bb.prov} / A_{c.eff}$ = **0.009**
Modular ratio	$\alpha_e = E_s / E_{cm}$ = **6.091**
Bond property coefficient	k_1 = **0.8**
Strain distribution coefficient	k_2 = **0.5**
	k_3 = **3.4**
	k_4 = **0.425**
Maximum crack spacing - exp.7.11	$s_{r.max} = k_3 \times c_{bb} + k_1 \times k_2 \times k_4 \times \phi_{bb} / \rho_{p.eff}$ = **478** mm
Maximum crack width - exp.7.8	$w_k = s_{r.max} \times \max(\sigma_s – k_t \times (f_{ct.eff} / \rho_{p.eff}) \times (1 + \alpha_e \times \rho_{p.eff}), 0.6 \times \sigma_s) / E_s$
	w_k = **0.049** mm
	w_k / w_{max} = **0.162**
	PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force	V = **11.7** kN/m
	$C_{Rd,c} = 0.18 / \gamma_C$ = **0.120**
	k = min(1 + √(200 mm / d), 2) = **2.000**
Longitudinal reinforcement ratio	$\rho_l = \min(A_{bb.prov} / d, 0.02)$ = **0.005**
	v_{min} = 0.035 N$^{1/2}$/mm × $k^{3/2} \times f_{ck}^{0.5}$ = **0.542** N/mm^2
Design shear resistance - exp.6.2a & 6.2b	$V_{Rd.c} = \max(C_{Rd.c} \times k \times (100$ N^2/mm$^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$
	$V_{Rd.c}$ = **69.3** kN/m
	$V / V_{Rd.c}$ = **0.169**
	PASS - Design shear resistance exceeds design shear force

Secondary transverse reinforcement to base - Section 9.3

Minimum area of reinforcement – cl.9.3.1.1(2)	$A_{bx.req} = 0.2 \times A_{bb.prov}$ = **113** mm^2/m
Maximum spacing of reinforcement – cl.9.3.1.1(3)	s_{bx_max} = **450** mm
Transverse reinforcement provided	10 dia.bars @ 200 c/c
Area of transverse reinforcement provided	$A_{bx.prov} = \pi \times \phi_{bx}^2 / (4 \times s_{bx})$ = **393** mm^2/m
	PASS - Area of reinforcement provided is greater than area of reinforcement required

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	Calcs for Rear garden wall				Start page no./Revision 8	
	Calcs by BR	Calcs date 22/12/2016	Checked by	Checked date	Approved by	Approved date