

Project name	Plaza Port Talbot		
Design note title	Assessment of Retaining Wall to Eagle Mews and Proposals		
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This technical note details the structural assessment of the existing retaining structures bordering the Plaza, Port Talbot site, specifically to Eagle Mews, and unclassified dead-end road serving existing residential properties.

1. EXISTING RETAINING WALLS - FORM

The existing retaining walls to Eagle Mews take two distinct forms:

- Wall A - An RC wall with RC piers of unknown construction type (i.e. embedded or bearing/cantilever) running broadly north-south directly adjacent the existing building (now demolished)
- Wall B - A brick masonry wall, assumed to be of mass construction, running from the north end of Wall A and following the Eagle Mews road line, eventually terminating at the intersection with Eagle Street

These distinct forms are illustrated below:



Both walls retain Eagle Mews, and have mixed soft and hard landscaping directly behind them, including areas of parking.

Wall A has a maximum retained height of approximately 1.2m, with the majority of the wall retaining significantly less.

Wall B has a maximum retained height of approximately 1.0m, with the majority of the wall retaining significantly less (or indeed not retaining at all).



2. EXISTING RETAINING WALLS - CONDITION

Wall A is generally in a fair to poor condition, with signs of concrete defects including spalling and exposed reinforcement throughout the length, consistent with similar defects observed to the existing building prior to demolition. However, the wall shows little to no signs of deformation via leaning or bowing. The above retained ground elements are of differing construction, including railings, blockwork and concrete wall, none of which are in particularly good structural condition.

Wall B is generally in good condition, showing little to no structural defects, aside from some minor cracks and localised displacement of upper bricks.

3. DEVELOPMENT PROPOSALS

The proposed development involves the demolition of the rear auditorium portion of the existing building, and replacement with a new structure, occupying the same footprint. The rear car park will be upgraded to serve the development. Furthermore, the alley that Wall A creates to Eagle Mews will be reduced in level to provide a DDA compliant escape route from different areas of the building, as well as housing proposed foul and surface water drainage from the new building.

The ground conditions on site have resulted in deep concrete pad and strip foundations for the proposed structure, whereas constraints around drainage, particularly the foul drainage exiting towards Talbot Road via the Eagle Mews "alley" create some deep drainage runs within the "alley". Finally, the proposals included reducing the levels in front of Wall A (and part of Wall B), thereby increasing the retained height and load upon the wall in the permanent condition.

The combination of these factors, along with unknown founding level of the existing walls, particularly Wall A, led to proposals for a new retaining wall adjacent Eagle Mews as part of the submitted planning application,

albeit with a caveat to make an assessment of the existing structures post-demolition of the building and prior to works to the walls. The proposals included in the planning application are included in Appendix A.

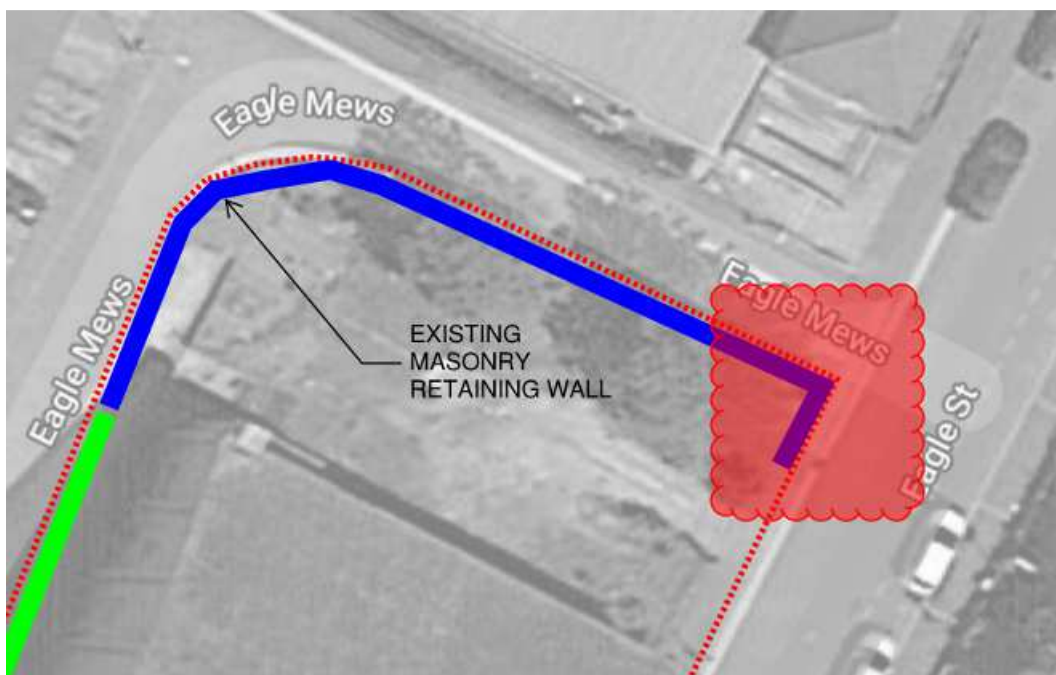
4. STRUCTURAL ASSESSMENT

Prior to any potential intrusive investigations into the walls themselves, the ground conditions directly behind the wall were first investigated to ascertain their properties, and any potential to treat the soils, thereby relieving load from the existing wall, and allowing a small increase in retained height in line with the proposals. Quantum Geotechnical were engaged to excavate a trial pit on site and provide an assessment. Their report is included in Appendix B.

In the intervening period while construction continued, a series of investigations, to include trial pits (for Walls A and B) and concrete investigations (for Wall A) were planned. However, these investigations were never undertaken, as explained in the subsequent section.

5. CONSTRUCTION OPERATIONS AND CURRENT SITUATION

In order to facilitate site access and demolition, part of the existing retaining wall where Eagle Mews meets Eagle Street has been removed, as indicated below.



During excavation operations to install foundations for the proposed building adjacent Eagle Mews, the existing Wall A was closely monitored given its unknown construction. During these operations, which included deep excavations, sections of the wall became unstable due to the unforeseen poor ground conditions at depth, requiring removal of a small section. Upon removal of this section, it became obvious that the wall was a) very thin in its construction and b) had no actual foundation, and instead the wall appeared to be a facing to the ground behind, as shown in the photo below.

In addition to the above, operations including demolition, stockpiling of materials and foundation excavations have resulted in collateral damage to Wall B. Furthermore, the anticipated construction operations to create the new car park - including drainage, bin store and surfacing - and the risks associated with the existing wall given the serious construction defects observed with Wall A, it is our recommendation that Wall B is also replaced.



Following this discovery, and as works progressed, it became apparent that the entire Wall A was similarly built, was deemed to be unsafe, and subsequently removed.

As such, the current situation on site is that there is no retaining wall present for the length of the former Wall A, and requires replacement.

6. UPDATED PROPOSALS

As part of the excavations for the foundations, and following removal of the existing wall, the area near Wall A was flooded with foundation concrete in order to ensure that a stable base could be provided for the new retaining wall without significant re-excavation.

Given the information herein, and in line with the planning application submitted and approved, the existing retaining walls (Wall A and Wall B) adjacent Eagle Mews will be replaced in their entirety to facilitate the development, and to ensure the on-going integrity of Eagle Mews itself.

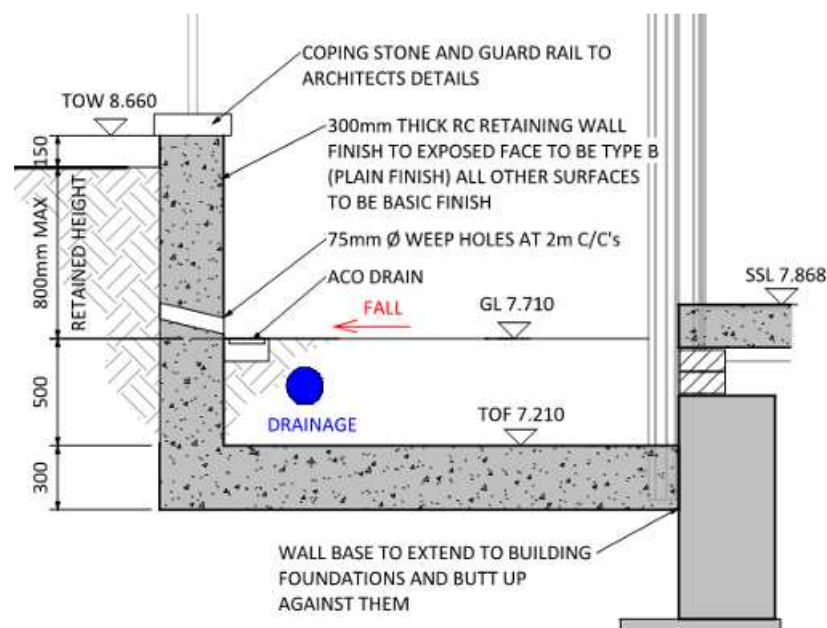
7. REPLACEMENT WALL DESIGNS

7.1 Wall A

Wall A sits adjacent to the new building, with a maximum retained height from proposed levels of circa 800mm.

During the construction works for the proposed building, a significant area and depth of the formation zone for the replacement wall in this area was dug and replaced with mass concrete. As such, a firm formation has already been provided for the proposed wall to be installed.

Therefore, the proposed replacement wall in this area will take the following form, accounting for both the retention of the highway (Eagle Mews), the proposed levels and the proposed drainage apparatus:



The proposed wall has been designed for all relevant soil loads, and an imposed surcharge load from the adjacent road of 15kN/m², representing a conservative approach given the normal vehicular traffic seen on the road itself.

A full calculation is provided in Appendix A

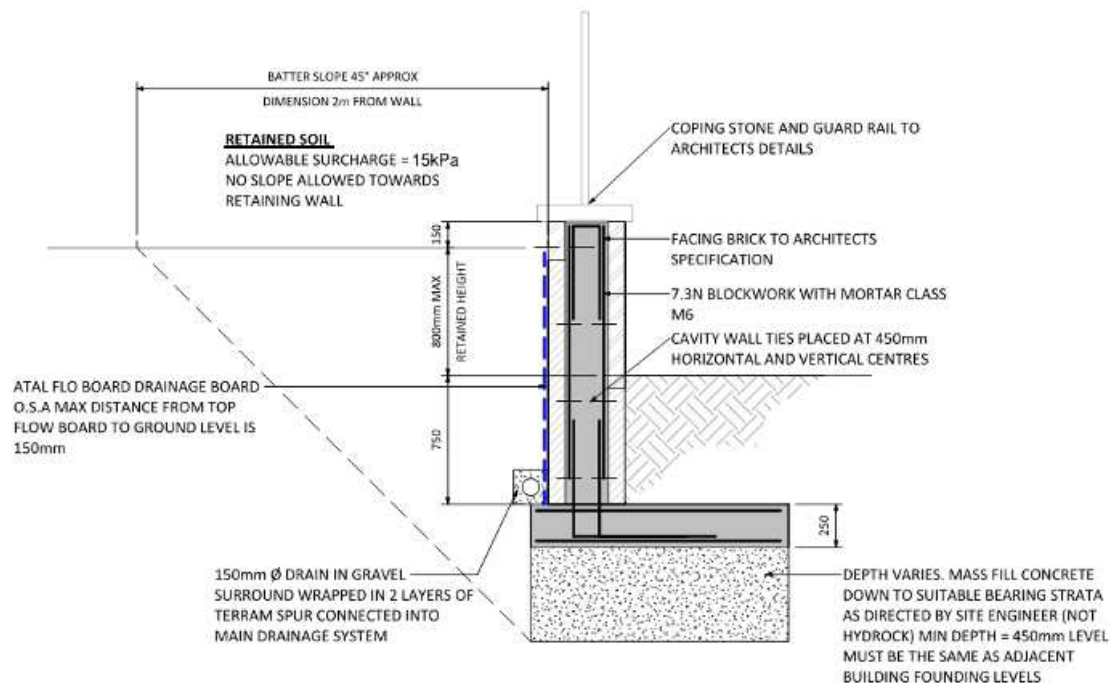
A drawing is provided in Appendix C

7.2 Wall B

Wall B encompasses the proposed car park to the rear of the proposed building, with a maximum retained height of circa 800mm

This section of wall will be founded on the same bearing strata as the building, and will include brick finish as per the planning application. As such, the wall has been design as an RC retaining wall with brick finish, with mass fill concrete included below in anticipation of deeper founding strata.

The proposed will take the following form:



The proposed wall has been designed for all relevant soil loads, and an imposed surcharge load from the adjacent road of 15kN/m², representing a conservative approach given the normal vehicular traffic seen on the road itself.

A full calculation is provided in Appendix B

A drawing is provided in Appendix C

Appendix A - Wall A Calculation

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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 2.9.02

Retaining wall details

Stem type	Cantilever
Stem height	$h_{\text{stem}} = 1450 \text{ mm}$
Stem thickness	$t_{\text{stem}} = 300 \text{ mm}$
Angle to rear face of stem	$\alpha = 90 \text{ deg}$
Stem density	$\gamma_{\text{stem}} = 25 \text{ kN/m}^3$
Toe length	$l_{\text{toe}} = 2400 \text{ mm}$
Base thickness	$t_{\text{base}} = 300 \text{ mm}$
Base density	$\gamma_{\text{base}} = 25 \text{ kN/m}^3$
Height of retained soil	$h_{\text{ret}} = 800 \text{ mm}$
Angle of soil surface	$\beta = 0 \text{ deg}$
Depth of cover	$d_{\text{cover}} = 500 \text{ mm}$
Depth of excavation	$d_{\text{exc}} = 150 \text{ mm}$

Retained soil properties

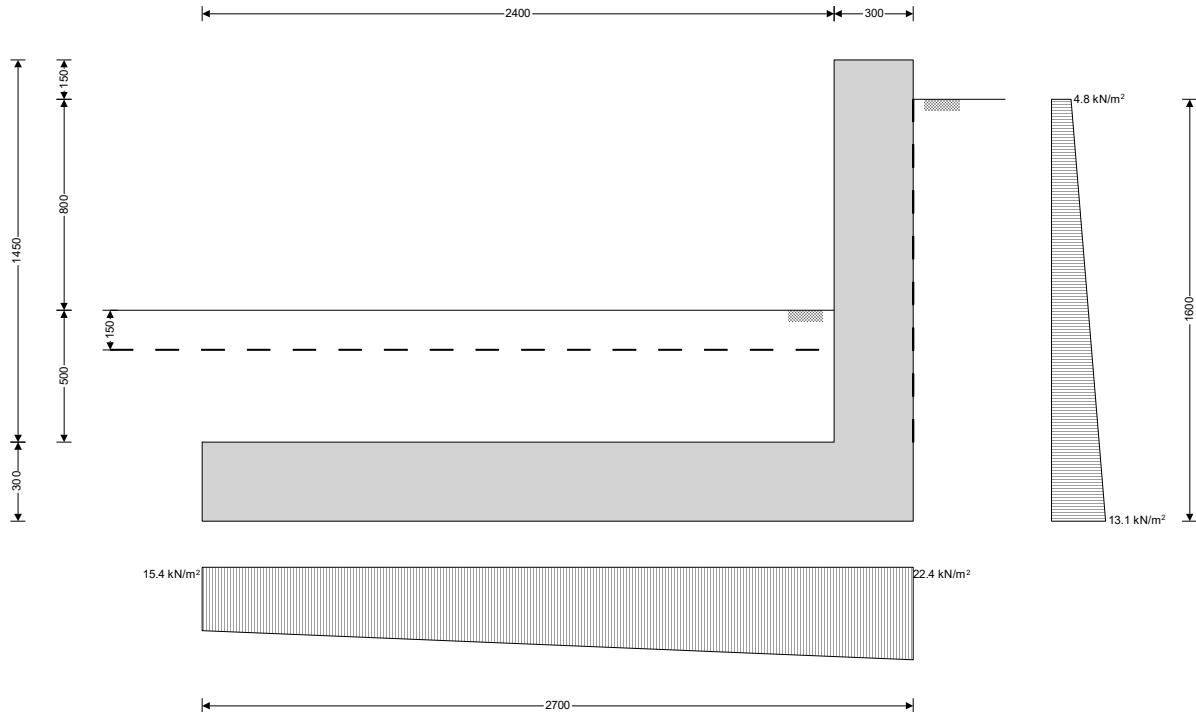
Soil type	Loose gravel
Moist density	$\gamma_{\text{mr}} = 16.5 \text{ kN/m}^3$
Saturated density	$\gamma_{\text{sr}} = 20.3 \text{ kN/m}^3$
Characteristic effective shear resistance angle	$\phi'_{\text{r,k}} = 28 \text{ deg}$
Characteristic wall friction angle	$\delta_{\text{r,k}} = 14 \text{ deg}$

Base soil properties

Soil type	Loose gravel
Soil density	$\gamma_{\text{b}} = 16.5 \text{ kN/m}^3$
Characteristic effective shear resistance angle	$\phi'_{\text{b,k}} = 28 \text{ deg}$
Characteristic wall friction angle	$\delta_{\text{b,k}} = 14 \text{ deg}$
Characteristic base friction angle	$\delta_{\text{bb,k}} = 18.7 \text{ deg}$
Presumed bearing capacity	$P_{\text{bearing}} = 80 \text{ kN/m}^2$

Loading details

Variable surcharge load	$\text{Surcharge}_Q = 15 \text{ kN/m}^2$
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General arrangement

Calculate retaining wall geometry

Base length

$$l_{base} = l_{toe} + t_{stem} = 2700 \text{ mm}$$

Moist soil height

$$h_{moist} = h_{soil} = 1300 \text{ mm}$$

Length of surcharge load

$$l_{sur} = l_{heel} = 0 \text{ mm}$$

- Distance to vertical component

$$x_{sur_v} = l_{base} - l_{heel} / 2 = 2700 \text{ mm}$$

Effective height of wall

$$h_{eff} = h_{base} + d_{cover} + h_{ret} = 1600 \text{ mm}$$

- Distance to horizontal component

$$x_{sur_h} = h_{eff} / 2 = 800 \text{ mm}$$

Area of wall stem

$$A_{stem} = h_{stem} \times t_{stem} = 0.435 \text{ m}^2$$

- Distance to vertical component

$$x_{stem} = l_{toe} + t_{stem} / 2 = 2550 \text{ mm}$$

Area of wall base

$$A_{base} = l_{base} \times t_{base} = 0.81 \text{ m}^2$$

- Distance to vertical component

$$x_{base} = l_{base} / 2 = 1350 \text{ mm}$$

Area of base soil

$$A_{pass} = d_{cover} \times l_{toe} = 1.2 \text{ m}^2$$

- Distance to vertical component

$$x_{pass_v} = l_{base} - (d_{cover} \times l_{toe} \times (l_{base} - l_{toe} / 2)) / A_{pass} = 1200 \text{ mm}$$

- Distance to horizontal component

$$x_{pass_h} = (d_{cover} + h_{base}) / 3 = 267 \text{ mm}$$

Area of excavated base soil

$$A_{exc} = h_{pass} \times l_{toe} = 0.84 \text{ m}^2$$

- Distance to vertical component

$$x_{exc_v} = l_{base} - (h_{pass} \times l_{toe} \times (l_{base} - l_{toe} / 2)) / A_{exc} = 1200 \text{ mm}$$

- Distance to horizontal component

$$x_{exc_h} = (h_{pass} + h_{base}) / 3 = 217 \text{ mm}$$

Using Coulomb theory

Active pressure coefficient

$$K_A = \sin(\alpha + \phi'_{r,k})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,k}) \times [1 + \sqrt{(\sin(\phi'_{r,k} + \delta_{r,k}) \times \sin(\phi'_{r,k} - \beta)) / (\sin(\alpha - \delta_{r,k}) \times \sin(\alpha + \beta))}]^2) = 0.326$$

Passive pressure coefficient

$$K_P = \sin(90 - \phi'_{b,k})^2 / (\sin(90 + \delta_{b,k}) \times [1 - \sqrt{(\sin(\phi'_{b,k} + \delta_{b,k}) \times \sin(\phi'_{b,k} - \beta)) / (\sin(90 + \delta_{b,k}))}]^2) = 4.325$$

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Bearing pressure check

Vertical forces on wall

Wall stem	$F_{\text{stem}} = A_{\text{stem}} \times \gamma_{\text{stem}} = 10.9 \text{ kN/m}$
Wall base	$F_{\text{base}} = A_{\text{base}} \times \gamma_{\text{base}} = 20.3 \text{ kN/m}$
Base soil	$F_{\text{pass}_v} = A_{\text{pass}} \times \gamma_b' = 19.8 \text{ kN/m}$
Total	$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{pass}_v} = 50.9 \text{ kN/m}$

Horizontal forces on wall

Surcharge load	$F_{\text{sur}_h} = K_A \times \cos(\delta_{r,d}) \times \text{Surcharge}_Q \times h_{\text{eff}} = 7.6 \text{ kN/m}$
Moist retained soil	$F_{\text{moist}_h} = K_A \times \cos(\delta_{r,d}) \times \gamma_{\text{mr}}' \times h_{\text{eff}}^2 / 2 = 6.7 \text{ kN/m}$
Base soil	$F_{\text{pass}_h} = \max(-K_P \times \cos(\delta_{b,d}) \times \gamma_b' \times (d_{\text{cover}} + h_{\text{base}})^2 / 2, -(F_{\text{moist}_h} + F_{\text{sur}_h})) = -14.3 \text{ kN/m}$
Total	$F_{\text{total}_h} = \max(F_{\text{moist}_h} + F_{\text{pass}_h} + F_{\text{sur}_h} - F_{\text{total}_v} \times \tan(\delta_{bb,d}), 0 \text{ kN/m}) = 0 \text{ kN/m}$

Moments on wall

Wall stem	$M_{\text{stem}} = F_{\text{stem}} \times x_{\text{stem}} = 27.7 \text{ kNm/m}$
Wall base	$M_{\text{base}} = F_{\text{base}} \times x_{\text{base}} = 27.3 \text{ kNm/m}$
Surcharge load	$M_{\text{sur}} = -F_{\text{sur}_h} \times x_{\text{sur}_h} = -6.1 \text{ kNm/m}$
Moist retained soil	$M_{\text{moist}} = -F_{\text{moist}_h} \times x_{\text{moist}_h} = -3.6 \text{ kNm/m}$
Base soil	$M_{\text{pass}} = F_{\text{pass}_v} \times x_{\text{pass}_v} - F_{\text{pass}_h} \times x_{\text{pass}_h} = 27.6 \text{ kNm/m}$
Total	$M_{\text{total}} = M_{\text{stem}} + M_{\text{base}} + M_{\text{moist}} + M_{\text{pass}} + M_{\text{sur}} = 73 \text{ kNm/m}$

Check bearing pressure

Distance to reaction	$\bar{x} = M_{\text{total}} / F_{\text{total}_v} = 1433 \text{ mm}$
Eccentricity of reaction	$e = \bar{x} - l_{\text{base}} / 2 = 83 \text{ mm}$
Loaded length of base	$l_{\text{load}} = l_{\text{base}} = 2700 \text{ mm}$
Bearing pressure at toe	$q_{\text{toe}} = F_{\text{total}_v} / l_{\text{base}} \times (1 - 6 \times e / l_{\text{base}}) = 15.4 \text{ kN/m}^2$
Bearing pressure at heel	$q_{\text{heel}} = F_{\text{total}_v} / l_{\text{base}} \times (1 + 6 \times e / l_{\text{base}}) = 22.4 \text{ kN/m}^2$
Factor of safety	$FoS_{\text{bp}} = P_{\text{bearing}} / \max(q_{\text{toe}}, q_{\text{heel}}) = 3.579$

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

Partial factors on actions - Table A.3 - Combination 1

Permanent unfavourable action	$\gamma_G = 1.35$
Permanent favourable action	$\gamma_{Gf} = 1.00$
Variable unfavourable action	$\gamma_Q = 1.50$
Variable favourable action	$\gamma_{Qf} = 0.00$

Partial factors for soil parameters – Table A.4 - Combination 1

Angle of shearing resistance	$\gamma_{\phi'} = 1.00$
Effective cohesion	$\gamma_{c'} = 1.00$
Weight density	$\gamma_Y = 1.00$

Retained soil properties

Design moist density	$\gamma_{\text{mr}}' = \gamma_{\text{mr}} / \gamma_Y = 16.5 \text{ kN/m}^3$
Design saturated density	$\gamma_{\text{sr}}' = \gamma_{\text{sr}} / \gamma_Y = 20.3 \text{ kN/m}^3$
Design effective shear resistance angle	$\phi'_{r,d} = \text{atan}(\tan(\phi'_{r,k}) / \gamma_{\phi'}) = 28 \text{ deg}$
Design wall friction angle	$\delta_{r,d} = \text{atan}(\tan(\delta_{r,k}) / \gamma_{\phi'}) = 14 \text{ deg}$

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Base soil properties

Design soil density

$$\gamma'_b = \gamma_b / \gamma_f = 16.5 \text{ kN/m}^3$$

Design effective shear resistance angle

$$\phi'_{b,d} = \text{atan}(\tan(\phi'_{b,k}) / \gamma_\phi) = 28 \text{ deg}$$

Design wall friction angle

$$\delta_{b,d} = \text{atan}(\tan(\delta_{b,k}) / \gamma_\phi) = 14 \text{ deg}$$

Design base friction angle

$$\delta_{bb,d} = \text{atan}(\tan(\delta_{bb,k}) / \gamma_\phi) = 18.7 \text{ deg}$$

Design effective cohesion

$$c'_{b,d} = c'_{b,k} / \gamma_c = 0 \text{ kN/m}^2$$

Using Coulomb theory

Active pressure coefficient

$$K_A = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times [1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))}]^2) = 0.326$$

Passive pressure coefficient

$$K_P = \sin(90 - \phi'_{b,d})^2 / (\sin(90 + \delta_{b,d}) \times [1 - \sqrt{(\sin(\phi'_{b,d} + \delta_{b,d}) \times \sin(\phi'_{b,d} - \beta) / (\sin(90 + \delta_{b,d}))}]^2) = 4.325$$

Sliding check

Vertical forces on wall

Wall stem

$$F_{\text{stem}} = \gamma_{\text{Gf}} \times A_{\text{stem}} \times \gamma_{\text{stem}} = 10.9 \text{ kN/m}$$

Wall base

$$F_{\text{base}} = \gamma_{\text{Gf}} \times A_{\text{base}} \times \gamma_{\text{base}} = 20.3 \text{ kN/m}$$

Base soil

$$F_{\text{exc}_v} = \gamma_{\text{Gf}} \times A_{\text{exc}} \times \gamma'_b = 13.9 \text{ kN/m}$$

Total

$$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{exc}_v} = 45 \text{ kN/m}$$

Horizontal forces on wall

Surcharge load

$$F_{\text{sur}_h} = K_A \times \cos(\delta_{r,d}) \times \gamma_Q \times \text{Surcharge}_Q \times h_{\text{eff}} = 11.4 \text{ kN/m}$$

Moist retained soil

$$F_{\text{moist}_h} = \gamma_G \times K_A \times \cos(\delta_{r,d}) \times \gamma_{\text{mr}} \times h_{\text{eff}}^2 / 2 = 9 \text{ kN/m}$$

Total

$$F_{\text{total}_h} = F_{\text{moist}_h} + F_{\text{sur}_h} = 20.4 \text{ kN/m}$$

Check stability against sliding

Base soil resistance

$$F_{\text{exc}_h} = \gamma_{\text{Gf}} \times K_P \times \cos(\delta_{b,d}) \times \gamma'_b \times (h_{\text{pass}} + h_{\text{base}})^2 / 2 = 14.6 \text{ kN/m}$$

Base friction

$$F_{\text{friction}} = F_{\text{total}_v} \times \tan(\delta_{bb,d}) = 15.2 \text{ kN/m}$$

Resistance to sliding

$$F_{\text{rest}} = F_{\text{exc}_h} + F_{\text{friction}} = 29.9 \text{ kN/m}$$

Factor of safety

$$\text{FoS}_{\text{sl}} = F_{\text{rest}} / F_{\text{total}_h} = 1.461$$

PASS - Resistance to sliding is greater than sliding force

Overtipping check

Vertical forces on wall

Wall stem

$$F_{\text{stem}} = \gamma_{\text{Gf}} \times A_{\text{stem}} \times \gamma_{\text{stem}} = 10.9 \text{ kN/m}$$

Wall base

$$F_{\text{base}} = \gamma_{\text{Gf}} \times A_{\text{base}} \times \gamma_{\text{base}} = 20.3 \text{ kN/m}$$

Base soil

$$F_{\text{exc}_v} = \gamma_{\text{Gf}} \times A_{\text{exc}} \times \gamma'_b = 13.9 \text{ kN/m}$$

Total

$$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{exc}_v} = 45 \text{ kN/m}$$

Horizontal forces on wall

Surcharge load

$$F_{\text{sur}_h} = K_A \times \cos(\delta_{r,d}) \times \gamma_Q \times \text{Surcharge}_Q \times h_{\text{eff}} = 11.4 \text{ kN/m}$$

Moist retained soil

$$F_{\text{moist}_h} = \gamma_G \times K_A \times \cos(\delta_{r,d}) \times \gamma_{\text{mr}} \times h_{\text{eff}}^2 / 2 = 9 \text{ kN/m}$$

Base soil

$$F_{\text{exc}_h} = -\gamma_{\text{Gf}} \times K_P \times \cos(\delta_{b,d}) \times \gamma'_b \times (h_{\text{pass}} + h_{\text{base}})^2 / 2 = -14.6 \text{ kN/m}$$

Total

$$F_{\text{total}_h} = F_{\text{moist}_h} + F_{\text{exc}_h} + F_{\text{sur}_h} = 5.8 \text{ kN/m}$$

Overtipping moments on wall

Surcharge load

$$M_{\text{sur}_\text{OT}} = F_{\text{sur}_h} \times x_{\text{sur}_h} = 9.1 \text{ kNm/m}$$

Moist retained soil

$$M_{\text{moist}_\text{OT}} = F_{\text{moist}_h} \times x_{\text{moist}_h} = 4.8 \text{ kNm/m}$$

Total

$$M_{\text{total}_\text{OT}} = M_{\text{moist}_\text{OT}} + M_{\text{sur}_\text{OT}} = 13.9 \text{ kNm/m}$$

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Restoring moments on wall

Wall stem	$M_{\text{stem}_R} = F_{\text{stem}} \times X_{\text{stem}} = 27.7 \text{ kNm/m}$
Wall base	$M_{\text{base}_R} = F_{\text{base}} \times X_{\text{base}} = 27.3 \text{ kNm/m}$
Base soil	$M_{\text{exc}_R} = F_{\text{exc}_v} \times X_{\text{exc}_v} - F_{\text{exc}_h} \times X_{\text{exc}_h} = 19.8 \text{ kNm/m}$
Total	$M_{\text{total}_R} = M_{\text{stem}_R} + M_{\text{base}_R} + M_{\text{exc}_R} = 74.9 \text{ kNm/m}$

Check stability against overturning

Factor of safety	$FoS_{ot} = M_{\text{total}_R} / M_{\text{total}_{OT}} = 5.372$
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PASS - Maximum restoring moment is greater than overturning moment

Partial factors on actions - Table A.3 - Combination 2

Permanent unfavourable action	$\gamma_G = 1.00$
Permanent favourable action	$\gamma_{Gf} = 1.00$
Variable unfavourable action	$\gamma_Q = 1.30$
Variable favourable action	$\gamma_{Qf} = 0.00$

Partial factors for soil parameters – Table A.4 - Combination 2

Angle of shearing resistance	$\gamma_{\phi'} = 1.25$
Effective cohesion	$\gamma_{c'} = 1.25$
Weight density	$\gamma_Y = 1.00$

Retained soil properties

Design moist density	$\gamma_{mr}' = \gamma_{mr} / \gamma_Y = 16.5 \text{ kN/m}^3$
Design saturated density	$\gamma_{sr}' = \gamma_{sr} / \gamma_Y = 20.3 \text{ kN/m}^3$
Design effective shear resistance angle	$\phi'_{r,d} = \text{atan}(\tan(\phi'_{r,k}) / \gamma_{\phi'}) = 23 \text{ deg}$
Design wall friction angle	$\delta_{r,d} = \text{atan}(\tan(\delta_{r,k}) / \gamma_{\phi'}) = 11.3 \text{ deg}$

Base soil properties

Design soil density	$\gamma_b' = \gamma_b / \gamma_Y = 16.5 \text{ kN/m}^3$
Design effective shear resistance angle	$\phi'_{b,d} = \text{atan}(\tan(\phi'_{b,k}) / \gamma_{\phi'}) = 23 \text{ deg}$
Design wall friction angle	$\delta_{b,d} = \text{atan}(\tan(\delta_{b,k}) / \gamma_{\phi'}) = 11.3 \text{ deg}$
Design base friction angle	$\delta_{bb,d} = \text{atan}(\tan(\delta_{bb,k}) / \gamma_{\phi'}) = 15.2 \text{ deg}$
Design effective cohesion	$c'_{b,d} = c'_{b,k} / \gamma_{c'} = 0 \text{ kN/m}^2$

Using Coulomb theory

Active pressure coefficient	$K_A = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times [1 + \sqrt{[\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))]}]) = 0.397$
Passive pressure coefficient	$K_P = \sin(90 - \phi'_{b,d})^2 / (\sin(90 + \delta_{b,d}) \times [1 - \sqrt{[\sin(\phi'_{b,d} + \delta_{b,d}) \times \sin(\phi'_{b,d}) / (\sin(90 + \delta_{b,d}))]}]) = 3.126$

Sliding check

Vertical forces on wall

Wall stem	$F_{\text{stem}} = \gamma_{Gf} \times A_{\text{stem}} \times \gamma_{\text{stem}} = 10.9 \text{ kN/m}$
Wall base	$F_{\text{base}} = \gamma_{Gf} \times A_{\text{base}} \times \gamma_{\text{base}} = 20.3 \text{ kN/m}$
Base soil	$F_{\text{exc}_v} = \gamma_{Gf} \times A_{\text{exc}} \times \gamma_b' = 13.9 \text{ kN/m}$
Total	$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{exc}_v} = 45 \text{ kN/m}$

Horizontal forces on wall

Surcharge load	$F_{\text{sur}_h} = K_A \times \cos(\delta_{r,d}) \times \gamma_Q \times \text{Surcharge}_Q \times h_{\text{eff}} = 12.2 \text{ kN/m}$
Moist retained soil	$F_{\text{moist}_h} = \gamma_G \times K_A \times \cos(\delta_{r,d}) \times \gamma_{mr}' \times h_{\text{eff}}^2 / 2 = 8.2 \text{ kN/m}$
Total	$F_{\text{total}_h} = F_{\text{moist}_h} + F_{\text{sur}_h} = 20.4 \text{ kN/m}$

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Check stability against sliding

Base soil resistance

$$F_{exc_h} = \gamma_{Gf} \times K_P \times \cos(\delta_{b,d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 = 10.7 \text{ kN/m}$$

Base friction

$$F_{friction} = F_{total_v} \times \tan(\delta_{bb,d}) = 12.2 \text{ kN/m}$$

Resistance to sliding

$$F_{rest} = F_{exc_h} + F_{friction} = 22.9 \text{ kN/m}$$

Factor of safety

$$FoS_{sl} = F_{rest} / F_{total_h} = 1.122$$

PASS - Resistance to sliding is greater than sliding force

Overturning check

Vertical forces on wall

Wall stem

$$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} = 10.9 \text{ kN/m}$$

Wall base

$$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} = 20.3 \text{ kN/m}$$

Base soil

$$F_{exc_v} = \gamma_{Gf} \times A_{exc} \times \gamma_b' = 13.9 \text{ kN/m}$$

Total

$$F_{total_v} = F_{stem} + F_{base} + F_{exc_v} = 45 \text{ kN/m}$$

Horizontal forces on wall

Surcharge load

$$F_{sur_h} = K_A \times \cos(\delta_{r,d}) \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff} = 12.2 \text{ kN/m}$$

Moist retained soil

$$F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r,d}) \times \gamma_{mr}' \times h_{eff}^2 / 2 = 8.2 \text{ kN/m}$$

Base soil

$$F_{exc_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b,d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 = -10.7 \text{ kN/m}$$

Total

$$F_{total_h} = F_{moist_h} + F_{exc_h} + F_{sur_h} = 9.7 \text{ kN/m}$$

Overturning moments on wall

Surcharge load

$$M_{sur_OT} = F_{sur_h} \times X_{sur_h} = 9.7 \text{ kNm/m}$$

Moist retained soil

$$M_{moist_OT} = F_{moist_h} \times X_{moist_h} = 4.4 \text{ kNm/m}$$

Total

$$M_{total_OT} = M_{moist_OT} + M_{sur_OT} = 14.1 \text{ kNm/m}$$

Restoring moments on wall

Wall stem

$$M_{stem_R} = F_{stem} \times X_{stem} = 27.7 \text{ kNm/m}$$

Wall base

$$M_{base_R} = F_{base} \times X_{base} = 27.3 \text{ kNm/m}$$

Base soil

$$M_{exc_R} = F_{exc_v} \times X_{exc_v} - F_{exc_h} \times X_{exc_h} = 18.9 \text{ kNm/m}$$

Total

$$M_{total_R} = M_{stem_R} + M_{base_R} + M_{exc_R} = 74 \text{ kNm/m}$$

Check stability against overturning

Factor of safety

$$FoS_{ot} = M_{total_R} / M_{total_OT} = 5.246$$

PASS - Maximum restoring moment is greater than overturning moment

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 2.9.02

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

Concrete strength class

C28/35

Characteristic compressive cylinder strength

$$f_{ck} = 28 \text{ N/mm}^2$$

Characteristic compressive cube strength

$$f_{ck,cube} = 35 \text{ N/mm}^2$$

Mean value of compressive cylinder strength

$$f_{cm} = f_{ck} + 8 \text{ N/mm}^2 = 36 \text{ N/mm}^2$$

Mean value of axial tensile strength

$$f_{ctm} = 0.3 \text{ N/mm}^2 \times (f_{ck} / 1 \text{ N/mm}^2)^{2/3} = 2.8 \text{ N/mm}^2$$

5% fractile of axial tensile strength

$$f_{ctk,0.05} = 0.7 \times f_{ctm} = 1.9 \text{ N/mm}^2$$

Secant modulus of elasticity of concrete

$$E_{cm} = 22 \text{ kN/mm}^2 \times (f_{cm} / 10 \text{ N/mm}^2)^{0.3} = 32308 \text{ N/mm}^2$$

Partial factor for concrete - Table 2.1N

$$\gamma_C = 1.50$$

Compressive strength coefficient - cl.3.1.6(1)

$$\alpha_{cc} = 0.85$$

Design compressive concrete strength - exp.3.15

$$f_{cd} = \alpha_{cc} \times f_{ck} / \gamma_C = 15.9 \text{ N/mm}^2$$

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Maximum aggregate size

$h_{agg} = 20 \text{ mm}$

Reinforcement details

Characteristic yield strength of reinforcement

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

Modulus of elasticity of reinforcement

$E_s = 200000 \text{ N/mm}^2$

Partial factor for reinforcing steel - Table 2.1N

$\gamma_s = 1.15$

Design yield strength of reinforcement

$f_{yd} = f_{yk} / \gamma_s = 435 \text{ N/mm}^2$

Cover to reinforcement

Front face of stem

$c_{sf} = 50 \text{ mm}$

Rear face of stem

$c_{sr} = 50 \text{ mm}$

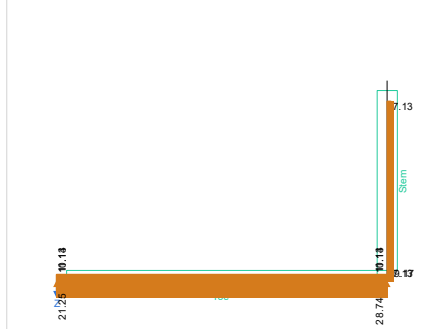
Top face of base

$c_{bt} = 50 \text{ mm}$

Bottom face of base

$c_{bb} = 75 \text{ mm}$

Loading details - Combination No.1 - kN/m²



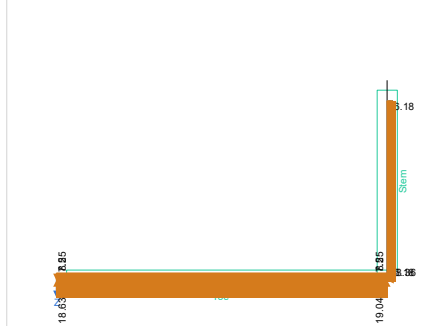
Shear force - Combination No.1 - kNm



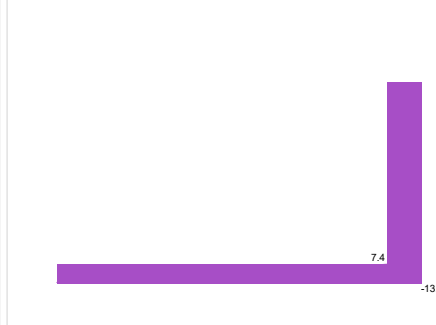
Bending moment - Combination No.1 - kNm/m



Loading details - Combination No.2 - kN/m²



Shear force - Combination No.2 - kNm



Bending moment - Combination No.2 - kNm/m



Check stem design at base of stem

Depth of section

$h = 300 \text{ mm}$

Rectangular section in flexure - Section 6.1

Design bending moment combination 1

$M = 8.6 \text{ kNm/m}$

Depth to tension reinforcement

$d = h - c_{sr} - \phi_{sr} / 2 = 245 \text{ mm}$

$K = M / (d^2 \times f_{ck}) = 0.005$

$K' = 0.207$

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

Lever arm

$z = \min(0.5 + 0.5 \times (1 - 3.53 \times K)^{0.5}, 0.95) \times d = 233 \text{ mm}$

Depth of neutral axis

$x = 2.5 \times (d - z) = 31 \text{ mm}$

Area of tension reinforcement required

$A_{sr,req} = M / (f_{yd} \times z) = 85 \text{ mm}^2/\text{m}$

Tension reinforcement provided

10 dia.bars @ 200 c/c

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Area of tension reinforcement provided

$$A_{sr,prov} = \pi \times \phi_{sr}^2 / (4 \times s_{sr}) = \mathbf{393 \text{ mm}^2/m}$$

Minimum area of reinforcement - exp.9.1N

$$A_{sr,min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = \mathbf{352 \text{ mm}^2/m}$$

Maximum area of reinforcement - cl.9.2.1.1(3)

$$A_{sr,max} = 0.04 \times h = \mathbf{12000 \text{ mm}^2/m}$$

$$\max(A_{sr,req}, A_{sr,min}) / A_{sr,prov} = \mathbf{0.897}$$

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

Deflection control - Section 7.4

Reference reinforcement ratio

$$\rho_0 = \sqrt{(f_{ck} / 1 \text{ N/mm}^2)} / 1000 = \mathbf{0.005}$$

Required tension reinforcement ratio

$$\rho = A_{sr,req} / d = \mathbf{0.000}$$

Required compression reinforcement ratio

$$\rho' = A_{sr,2,req} / d_2 = \mathbf{0.000}$$

Structural system factor - Table 7.4N

$$K_b = \mathbf{0.4}$$

Reinforcement factor - exp.7.17

$$K_s = \min(500 \text{ N/mm}^2 / (f_{yk} \times A_{sr,req} / A_{sr,prov}), 1.5) = \mathbf{1.5}$$

Limiting span to depth ratio - exp.7.16.a

$$\min(K_s \times K_b \times [11 + 1.5 \times \sqrt{(f_{ck} / 1 \text{ N/mm}^2)} \times \rho_0 / \rho + 3.2 \times \sqrt{(f_{ck} / 1 \text{ N/mm}^2)} \times (\rho_0 / \rho - 1)^{3/2}], 40 \times K_b) = \mathbf{16}$$

Actual span to depth ratio

$$h_{stem} / d = \mathbf{5.9}$$

PASS - Span to depth ratio is less than deflection control limit

Crack control - Section 7.3

Limiting crack width

$$w_{max} = \mathbf{0.3 \text{ mm}}$$

Variable load factor - EN1990 – Table A1.1

$$\psi_2 = \mathbf{0.6}$$

Serviceability bending moment

$$M_{sls} = \mathbf{4.3 \text{ kNm/m}}$$

Tensile stress in reinforcement

$$\sigma_s = M_{sls} / (A_{sr,prov} \times z) = \mathbf{47.3 \text{ N/mm}^2}$$

Load duration

Long term

Load duration factor

$$k_t = \mathbf{0.4}$$

Effective area of concrete in tension

$$A_{c,eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2) = \mathbf{89792 \text{ mm}^2/m}$$

Mean value of concrete tensile strength

$$f_{ct,eff} = f_{ctm} = \mathbf{2.8 \text{ N/mm}^2}$$

Reinforcement ratio

$$\rho_{p,eff} = A_{sr,prov} / A_{c,eff} = \mathbf{0.004}$$

Modular ratio

$$\alpha_e = E_s / E_{cm} = \mathbf{6.19}$$

Bond property coefficient

$$k_1 = \mathbf{0.8}$$

Strain distribution coefficient

$$k_2 = \mathbf{0.5}$$

$$k_3 = \mathbf{3.4}$$

$$k_4 = \mathbf{0.425}$$

Maximum crack spacing - exp.7.11

$$s_{r,max} = k_3 \times c_{sr} + k_1 \times k_2 \times k_4 \times \phi_{sr} / \rho_{p,eff} = \mathbf{559 \text{ mm}}$$

Maximum crack width - exp.7.8

$$w_k = s_{r,max} \times \max(\sigma_s - k_t \times (f_{ct,eff} / \rho_{p,eff}) \times (1 + \alpha_e \times \rho_{p,eff}), 0.6 \times \sigma_s) / E_s$$

$$w_k = \mathbf{0.079 \text{ mm}}$$

$$w_k / w_{max} = \mathbf{0.264}$$

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force

$$V = \mathbf{15.2 \text{ kN/m}}$$

$$C_{Rd,c} = 0.18 / \gamma_c = \mathbf{0.120}$$

$$k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2) = \mathbf{1.904}$$

Longitudinal reinforcement ratio

$$\rho_l = \min(A_{sr,prov} / d, 0.02) = \mathbf{0.002}$$

$$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5} = \mathbf{0.486 \text{ N/mm}^2}$$

Design shear resistance - exp.6.2a & 6.2b

$$V_{Rd,c} = \max(C_{Rd,c} \times k \times (100 \text{ N}^2/\text{mm}^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$$

$$V_{Rd,c} = \mathbf{119.2 \text{ kN/m}}$$

$$V / V_{Rd,c} = \mathbf{0.128}$$

PASS - Design shear resistance exceeds design shear force

Horizontal reinforcement parallel to face of stem - Section 9.6

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Minimum area of reinforcement – cl.9.6.3(1) $A_{sx,req} = \max(0.25 \times A_{sr,prov}, 0.001 \times t_{stem}) = 300 \text{ mm}^2/\text{m}$

Maximum spacing of reinforcement – cl.9.6.3(2) $s_{sx,max} = 400 \text{ mm}$

Transverse reinforcement provided 10 dia.bars @ 200 c/c

Area of transverse reinforcement provided $A_{sx,prov} = \pi \times \phi_{sx}^2 / (4 \times s_{sx}) = 393 \text{ mm}^2/\text{m}$

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

Check base design at toe

Depth of section $h = 300 \text{ mm}$

Rectangular section in flexure - Section 6.1

Design bending moment combination 2 $M = 8.7 \text{ kNm/m}$

Depth to tension reinforcement $d = h - c_{bb} - \phi_{bb} / 2 = 220 \text{ mm}$

$K = M / (d^2 \times f_{ck}) = 0.006$

$K' = 0.207$

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

Lever arm $z = \min(0.5 + 0.5 \times (1 - 3.53 \times K)^{0.5}, 0.95) \times d = 209 \text{ mm}$

Depth of neutral axis $x = 2.5 \times (d - z) = 28 \text{ mm}$

Area of tension reinforcement required $A_{bb,req} = M / (f_{yd} \times z) = 96 \text{ mm}^2/\text{m}$

Tension reinforcement provided 10 dia.bars @ 200 c/c

Area of tension reinforcement provided $A_{bb,prov} = \pi \times \phi_{bb}^2 / (4 \times s_{bb}) = 393 \text{ mm}^2/\text{m}$

Minimum area of reinforcement - exp.9.1N $A_{bb,min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = 316 \text{ mm}^2/\text{m}$

Maximum area of reinforcement - cl.9.2.1.1(3) $A_{bb,max} = 0.04 \times h = 12000 \text{ mm}^2/\text{m}$

$\max(A_{bb,req}, A_{bb,min}) / A_{bb,prov} = 0.806$

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

Crack control - Section 7.3

Limiting crack width $w_{max} = 0.3 \text{ mm}$

Variable load factor - EN1990 – Table A1.1 $\psi_2 = 0.6$

Serviceability bending moment $M_{sls} = 4.9 \text{ kNm/m}$

Tensile stress in reinforcement $\sigma_s = M_{sls} / (A_{bb,prov} \times z) = 59.2 \text{ N/mm}^2$

Load duration Long term

Load duration factor $k_t = 0.4$

Effective area of concrete in tension $A_{c,eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2) = 90833 \text{ mm}^2/\text{m}$

Mean value of concrete tensile strength $f_{ct,eff} = f_{ctm} = 2.8 \text{ N/mm}^2$

Reinforcement ratio $\rho_{p,eff} = A_{bb,prov} / A_{c,eff} = 0.004$

Modular ratio $\alpha_e = E_s / E_{cm} = 6.19$

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 $s_{r,max} = k_3 \times c_{bb} + k_1 \times k_2 \times k_4 \times \phi_{bb} / \rho_{p,eff} = 648 \text{ mm}$

Maximum crack width - exp.7.8 $w_k = s_{r,max} \times \max(\sigma_s - k_t \times (f_{ct,eff} / \rho_{p,eff}) \times (1 + \alpha_e \times \rho_{p,eff}), 0.6 \times \sigma_s) / E_s$

$w_k = 0.115 \text{ mm}$

$w_k / w_{max} = 0.384$

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force $V = 9 \text{ kN/m}$

$C_{Rd,c} = 0.18 / \gamma_c = 0.120$

$k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2) = 1.953$

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Calcs for				Start page no./Revision 10	
Calcs by M	Calcs date 23/02/2021	Checked by	Checked date	Approved by	Approved date

Longitudinal reinforcement ratio

$$\rho_l = \min(A_{bb,prov} / d, 0.02) = \mathbf{0.002}$$

$$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5} = \mathbf{0.506 \text{ N/mm}^2}$$

Design shear resistance - exp.6.2a & 6.2b

$$V_{Rd,c} = \max(C_{Rd,c} \times k \times (100 \text{ N}^2/\text{mm}^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$$

$$V_{Rd,c} = \mathbf{111.2 \text{ kN/m}}$$

$$V / V_{Rd,c} = \mathbf{0.081}$$

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)

$$A_{bx,req} = 0.2 \times A_{bb,prov} = \mathbf{79 \text{ mm}^2/\text{m}}$$

Maximum spacing of reinforcement – cl.9.3.1.1(3)

$$s_{bx,max} = \mathbf{450 \text{ mm}}$$

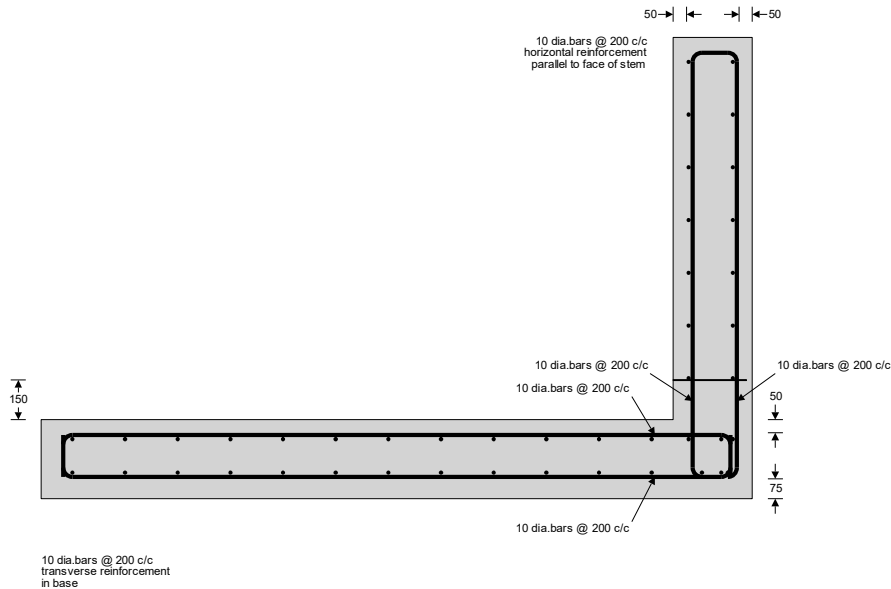
Transverse reinforcement provided

$$\mathbf{10 \text{ dia. bars @ } 200 \text{ c/c}}$$

Area of transverse reinforcement provided

$$A_{bx,prov} = \pi \times \phi_{bx}^2 / (4 \times s_{bx}) = \mathbf{393 \text{ mm}^2/\text{m}}$$

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



Reinforcement details

Appendix B - Wall B Calculation

Project Port Talbot Plaza				Job no.	
Calcs for Retaining Wall - Stem reinforcement check				Start page no./Revision 1	
Calcs by PJ	Calcs date 23/02/2021	Checked by	Checked date	Approved by	Approved date

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 2.9.02

Retaining wall details

Stem type	Cantilever
Stem height	$h_{\text{stem}} = 1700 \text{ mm}$
Stem thickness	$t_{\text{stem}} = 250 \text{ mm}$
Angle to rear face of stem	$\alpha = 90 \text{ deg}$
Stem density	$\gamma_{\text{stem}} = 25 \text{ kN/m}^3$
Toe length	$l_{\text{toe}} = 850 \text{ mm}$
Heel length	$l_{\text{heel}} = 200 \text{ mm}$
Base thickness	$t_{\text{base}} = 250 \text{ mm}$
Base density	$\gamma_{\text{base}} = 25 \text{ kN/m}^3$
Height of retained soil	$h_{\text{ret}} = 800 \text{ mm}$
Angle of soil surface	$\beta = 0 \text{ deg}$
Depth of cover	$d_{\text{cover}} = 750 \text{ mm}$
Depth of excavation	$d_{\text{exc}} = 150 \text{ mm}$

Retained soil properties

Soil type	Medium dense fine or silty sand
Moist density	$\gamma_{\text{mr}} = 19 \text{ kN/m}^3$
Saturated density	$\gamma_{\text{sr}} = 21 \text{ kN/m}^3$
Characteristic effective shear resistance angle	$\phi'_{\text{r,k}} = 30 \text{ deg}$
Characteristic wall friction angle	$\delta_{\text{r,k}} = 15 \text{ deg}$

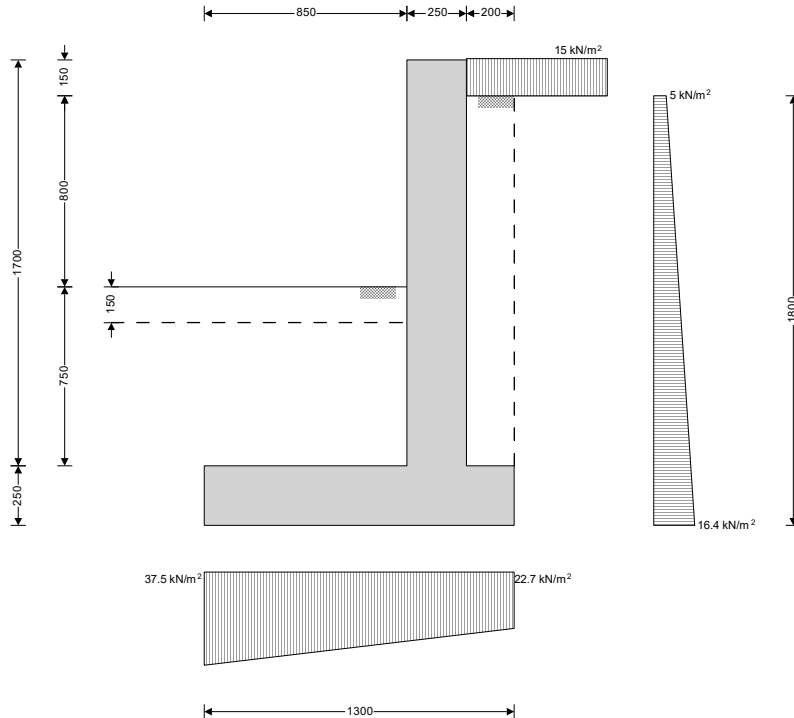
Base soil properties

Soil type	Medium dense fine or silty sand
Soil density	$\gamma_{\text{b}} = 18 \text{ kN/m}^3$
Characteristic effective shear resistance angle	$\phi'_{\text{b,k}} = 30 \text{ deg}$
Characteristic wall friction angle	$\delta_{\text{b,k}} = 15 \text{ deg}$
Characteristic base friction angle	$\delta_{\text{bb,k}} = 30 \text{ deg}$
Presumed bearing capacity	$P_{\text{bearing}} = 225 \text{ kN/m}^2$

Loading details

Variable surcharge load	Surcharge _Q = 15 kN/m ²
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Project Port Talbot Plaza				Job no.	
Calcs for Retaining Wall - Stem reinforcement check				Start page no./Revision 2	
Calcs by PJ	Calcs date 23/02/2021	Checked by	Checked date	Approved by	Approved date



General arrangement

Calculate retaining wall geometry

Base length

$$l_{\text{base}} = l_{\text{toe}} + t_{\text{stem}} + l_{\text{heel}} = 1300 \text{ mm}$$

Moist soil height

$$h_{\text{moist}} = h_{\text{soil}} = 1550 \text{ mm}$$

Length of surcharge load

$$l_{\text{sur}} = l_{\text{heel}} = 200 \text{ mm}$$

- Distance to vertical component

$$x_{\text{sur}_v} = l_{\text{base}} - l_{\text{heel}} / 2 = 1200 \text{ mm}$$

Effective height of wall

$$h_{\text{eff}} = h_{\text{base}} + d_{\text{cover}} + h_{\text{ret}} = 1800 \text{ mm}$$

- Distance to horizontal component

$$x_{\text{sur}_h} = h_{\text{eff}} / 2 = 900 \text{ mm}$$

Area of wall stem

$$A_{\text{stem}} = h_{\text{stem}} \times t_{\text{stem}} = 0.425 \text{ m}^2$$

- Distance to vertical component

$$x_{\text{stem}} = l_{\text{toe}} + t_{\text{stem}} / 2 = 975 \text{ mm}$$

Area of wall base

$$A_{\text{base}} = l_{\text{base}} \times t_{\text{base}} = 0.325 \text{ m}^2$$

- Distance to vertical component

$$x_{\text{base}} = l_{\text{base}} / 2 = 650 \text{ mm}$$

Area of moist soil

$$A_{\text{moist}} = h_{\text{moist}} \times l_{\text{heel}} = 0.31 \text{ m}^2$$

- Distance to vertical component

$$x_{\text{moist}_v} = l_{\text{base}} - (h_{\text{moist}} \times l_{\text{heel}}^2 / 2) / A_{\text{moist}} = 1200 \text{ mm}$$

- Distance to horizontal component

$$x_{\text{moist}_h} = h_{\text{eff}} / 3 = 600 \text{ mm}$$

Area of base soil

$$A_{\text{pass}} = d_{\text{cover}} \times l_{\text{toe}} = 0.638 \text{ m}^2$$

- Distance to vertical component

$$x_{\text{pass}_v} = l_{\text{base}} - (d_{\text{cover}} \times l_{\text{toe}} \times (l_{\text{base}} - l_{\text{toe}} / 2)) / A_{\text{pass}} = 425 \text{ mm}$$

- Distance to horizontal component

$$x_{\text{pass}_h} = (d_{\text{cover}} + h_{\text{base}}) / 3 = 333 \text{ mm}$$

Area of excavated base soil

$$A_{\text{exc}} = h_{\text{pass}} \times l_{\text{toe}} = 0.51 \text{ m}^2$$

- Distance to vertical component

$$x_{\text{exc}_v} = l_{\text{base}} - (h_{\text{pass}} \times l_{\text{toe}} \times (l_{\text{base}} - l_{\text{toe}} / 2)) / A_{\text{exc}} = 425 \text{ mm}$$

- Distance to horizontal component

$$x_{\text{exc}_h} = (h_{\text{pass}} + h_{\text{base}}) / 3 = 283 \text{ mm}$$

Using Rankine theory

Active pressure coefficient

$$K_A = (1 - \sin(\phi'_{r,k})) / (1 + \sin(\phi'_{r,k})) = 0.333$$

Project Port Talbot Plaza				Job no.	
Calcs for Retaining Wall - Stem reinforcement check				Start page no./Revision 3	
Calcs by PJ	Calcs date 23/02/2021	Checked by	Checked date	Approved by	Approved date

Passive pressure coefficient

$$K_P = (1 + \sin(\phi'_{b,k})) / (1 - \sin(\phi'_{b,k})) = \mathbf{3.000}$$

Bearing pressure check

Vertical forces on wall

Wall stem

$$F_{\text{stem}} = A_{\text{stem}} \times \gamma_{\text{stem}} = \mathbf{10.6 \text{ kN/m}}$$

Wall base

$$F_{\text{base}} = A_{\text{base}} \times \gamma_{\text{base}} = \mathbf{8.1 \text{ kN/m}}$$

Surcharge load

$$F_{\text{sur}_v} = \text{Surcharge}_Q \times l_{\text{heel}} = \mathbf{3 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_v} = A_{\text{moist}} \times \gamma_{\text{mr}}' = \mathbf{5.9 \text{ kN/m}}$$

Base soil

$$F_{\text{pass}_v} = A_{\text{pass}} \times \gamma_b' = \mathbf{11.5 \text{ kN/m}}$$

Total

$$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{moist}_v} + F_{\text{pass}_v} + F_{\text{sur}_v} = \mathbf{39.1 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{\text{sur}_h} = K_A \times \text{Surcharge}_Q \times h_{\text{eff}} = \mathbf{9 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_h} = K_A \times \gamma_{\text{mr}}' \times h_{\text{eff}}^2 / 2 = \mathbf{10.3 \text{ kN/m}}$$

Base soil

$$F_{\text{pass}_h} = \max(-K_P \times \gamma_b' \times (d_{\text{cover}} + h_{\text{base}})^2 / 2, -(F_{\text{moist}_h} + F_{\text{sur}_h})) = \mathbf{-19.3 \text{ kN/m}}$$

Total

$$F_{\text{total}_h} = \max(F_{\text{moist}_h} + F_{\text{pass}_h} + F_{\text{sur}_h} - F_{\text{total}_v} \times \tan(\delta_{\text{bb},d}), 0 \text{ kN/m}) = \mathbf{0 \text{ kN/m}}$$

Moments on wall

Wall stem

$$M_{\text{stem}} = F_{\text{stem}} \times x_{\text{stem}} = \mathbf{10.4 \text{ kNm/m}}$$

Wall base

$$M_{\text{base}} = F_{\text{base}} \times x_{\text{base}} = \mathbf{5.3 \text{ kNm/m}}$$

Surcharge load

$$M_{\text{sur}} = F_{\text{sur}_v} \times x_{\text{sur}_v} - F_{\text{sur}_h} \times x_{\text{sur}_h} = \mathbf{-4.5 \text{ kNm/m}}$$

Moist retained soil

$$M_{\text{moist}} = F_{\text{moist}_v} \times x_{\text{moist}_v} - F_{\text{moist}_h} \times x_{\text{moist}_h} = \mathbf{0.9 \text{ kNm/m}}$$

Base soil

$$M_{\text{pass}} = F_{\text{pass}_v} \times x_{\text{pass}_v} - F_{\text{pass}_h} \times x_{\text{pass}_h} = \mathbf{11.3 \text{ kNm/m}}$$

Total

$$M_{\text{total}} = M_{\text{stem}} + M_{\text{base}} + M_{\text{moist}} + M_{\text{pass}} + M_{\text{sur}} = \mathbf{23.3 \text{ kNm/m}}$$

Check bearing pressure

Distance to reaction

$$\bar{x} = M_{\text{total}} / F_{\text{total}_v} = \mathbf{597 \text{ mm}}$$

Eccentricity of reaction

$$e = \bar{x} - l_{\text{base}} / 2 = \mathbf{-53 \text{ mm}}$$

Loaded length of base

$$l_{\text{load}} = l_{\text{base}} = \mathbf{1300 \text{ mm}}$$

Bearing pressure at toe

$$q_{\text{toe}} = F_{\text{total}_v} / l_{\text{base}} \times (1 - 6 \times e / l_{\text{base}}) = \mathbf{37.5 \text{ kN/m}^2}$$

Bearing pressure at heel

$$q_{\text{heel}} = F_{\text{total}_v} / l_{\text{base}} \times (1 + 6 \times e / l_{\text{base}}) = \mathbf{22.7 \text{ kN/m}^2}$$

Factor of safety

$$FoS_{\text{bp}} = P_{\text{bearing}} / \max(q_{\text{toe}}, q_{\text{heel}}) = \mathbf{6.007}$$

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

Partial factors on actions - Table A.3 - Combination 1

Permanent unfavourable action

$$\gamma_G = \mathbf{1.35}$$

Permanent favourable action

$$\gamma_{\text{Gr}} = \mathbf{1.00}$$

Variable unfavourable action

$$\gamma_Q = \mathbf{1.50}$$

Variable favourable action

$$\gamma_{\text{Qr}} = \mathbf{0.00}$$

Partial factors for soil parameters – Table A.4 - Combination 1

Angle of shearing resistance

$$\gamma_{\phi'} = \mathbf{1.00}$$

Effective cohesion

$$\gamma_{c'} = \mathbf{1.00}$$

Weight density

$$\gamma_{\gamma} = \mathbf{1.00}$$

Retained soil properties

Design moist density

$$\gamma_{\text{mr}}' = \gamma_{\text{mr}} / \gamma_{\gamma} = \mathbf{19 \text{ kN/m}^3}$$

Design saturated density

$$\gamma_{\text{sr}}' = \gamma_{\text{sr}} / \gamma_{\gamma} = \mathbf{21 \text{ kN/m}^3}$$

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Design effective shear resistance angle

$$\phi'_{r,d} = \text{atan}(\tan(\phi'_{r,k}) / \gamma_{\phi'}) = \mathbf{30 \text{ deg}}$$

Design wall friction angle

$$\delta_{r,d} = \text{atan}(\tan(\delta_{r,k}) / \gamma_{\phi'}) = \mathbf{15 \text{ deg}}$$

Base soil properties

Design soil density

$$\gamma_b' = \gamma_b / \gamma_f = \mathbf{18 \text{ kN/m}^3}$$

Design effective shear resistance angle

$$\phi'_{b,d} = \text{atan}(\tan(\phi'_{b,k}) / \gamma_{\phi'}) = \mathbf{30 \text{ deg}}$$

Design wall friction angle

$$\delta_{b,d} = \text{atan}(\tan(\delta_{b,k}) / \gamma_{\phi'}) = \mathbf{15 \text{ deg}}$$

Design base friction angle

$$\delta_{bb,d} = \text{atan}(\tan(\delta_{bb,k}) / \gamma_{\phi'}) = \mathbf{30 \text{ deg}}$$

Design effective cohesion

$$c'_{b,d} = c'_{b,k} / \gamma_{c'} = \mathbf{0 \text{ kN/m}^2}$$

Using Rankine theory

Active pressure coefficient

$$K_A = (1 - \sin(\phi'_{r,d})) / (1 + \sin(\phi'_{r,d})) = \mathbf{0.333}$$

Passive pressure coefficient

$$K_P = (1 + \sin(\phi'_{b,d})) / (1 - \sin(\phi'_{b,d})) = \mathbf{3.000}$$

Sliding check

Vertical forces on wall

Wall stem

$$F_{\text{stem}} = \gamma_{Gf} \times A_{\text{stem}} \times \gamma_{\text{stem}} = \mathbf{10.6 \text{ kN/m}}$$

Wall base

$$F_{\text{base}} = \gamma_{Gf} \times A_{\text{base}} \times \gamma_{\text{base}} = \mathbf{8.1 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_v} = \gamma_{Gf} \times A_{\text{moist}} \times \gamma_{mr}' = \mathbf{5.9 \text{ kN/m}}$$

Base soil

$$F_{\text{exc}_v} = \gamma_{Gf} \times A_{\text{exc}} \times \gamma_b' = \mathbf{9.2 \text{ kN/m}}$$

Total

$$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{moist}_v} + F_{\text{exc}_v} = \mathbf{33.8 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{\text{sur}_h} = K_A \times \gamma_Q \times \text{Surcharge}_Q \times h_{\text{eff}} = \mathbf{13.5 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_h} = \gamma_G \times K_A \times \gamma_{mr}' \times h_{\text{eff}}^2 / 2 = \mathbf{13.9 \text{ kN/m}}$$

Total

$$F_{\text{total}_h} = F_{\text{moist}_h} + F_{\text{sur}_h} = \mathbf{27.4 \text{ kN/m}}$$

Check stability against sliding

Base soil resistance

$$F_{\text{exc}_h} = \gamma_{Gf} \times K_P \times \gamma_b' \times (h_{\text{pass}} + h_{\text{base}})^2 / 2 = \mathbf{19.5 \text{ kN/m}}$$

Base friction

$$F_{\text{friction}} = F_{\text{total}_v} \times \tan(\delta_{bb,d}) = \mathbf{19.5 \text{ kN/m}}$$

Resistance to sliding

$$F_{\text{rest}} = F_{\text{exc}_h} + F_{\text{friction}} = \mathbf{39 \text{ kN/m}}$$

Factor of safety

$$FoS_{sl} = F_{\text{rest}} / F_{\text{total}_h} = \mathbf{1.427}$$

PASS - Resistance to sliding is greater than sliding force

Overturning check

Vertical forces on wall

Wall stem

$$F_{\text{stem}} = \gamma_{Gf} \times A_{\text{stem}} \times \gamma_{\text{stem}} = \mathbf{10.6 \text{ kN/m}}$$

Wall base

$$F_{\text{base}} = \gamma_{Gf} \times A_{\text{base}} \times \gamma_{\text{base}} = \mathbf{8.1 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_v} = \gamma_{Gf} \times A_{\text{moist}} \times \gamma_{mr}' = \mathbf{5.9 \text{ kN/m}}$$

Base soil

$$F_{\text{exc}_v} = \gamma_{Gf} \times A_{\text{exc}} \times \gamma_b' = \mathbf{9.2 \text{ kN/m}}$$

Total

$$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{moist}_v} + F_{\text{exc}_v} = \mathbf{33.8 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{\text{sur}_h} = K_A \times \gamma_Q \times \text{Surcharge}_Q \times h_{\text{eff}} = \mathbf{13.5 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_h} = \gamma_G \times K_A \times \gamma_{mr}' \times h_{\text{eff}}^2 / 2 = \mathbf{13.9 \text{ kN/m}}$$

Base soil

$$F_{\text{exc}_h} = -\gamma_{Gf} \times K_P \times \gamma_b' \times (h_{\text{pass}} + h_{\text{base}})^2 / 2 = \mathbf{-19.5 \text{ kN/m}}$$

Total

$$F_{\text{total}_h} = F_{\text{moist}_h} + F_{\text{exc}_h} + F_{\text{sur}_h} = \mathbf{7.8 \text{ kN/m}}$$

Overturning moments on wall

Surcharge load

$$M_{\text{sur}_OT} = F_{\text{sur}_h} \times x_{\text{sur}_h} = \mathbf{12.2 \text{ kNm/m}}$$

Moist retained soil

$$M_{\text{moist}_OT} = F_{\text{moist}_h} \times x_{\text{moist}_h} = \mathbf{8.3 \text{ kNm/m}}$$

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Total

$$M_{total_OT} = M_{moist_OT} + M_{sur_OT} = \mathbf{20.5 \text{ kNm/m}}$$

Restoring moments on wall

Wall stem

$$M_{stem_R} = F_{stem} \times X_{stem} = \mathbf{10.4 \text{ kNm/m}}$$

Wall base

$$M_{base_R} = F_{base} \times X_{base} = \mathbf{5.3 \text{ kNm/m}}$$

Moist retained soil

$$M_{moist_R} = F_{moist_v} \times X_{moist_v} = \mathbf{7.1 \text{ kNm/m}}$$

Base soil

$$M_{exc_R} = F_{exc_v} \times X_{exc_v} - F_{exc_h} \times X_{exc_h} = \mathbf{9.4 \text{ kNm/m}}$$

Total

$$M_{total_R} = M_{stem_R} + M_{base_R} + M_{moist_R} + M_{exc_R} = \mathbf{32.1 \text{ kNm/m}}$$

Check stability against overturning

Factor of safety

$$FoS_{OT} = M_{total_R} / M_{total_OT} = \mathbf{1.571}$$

PASS - Maximum restoring moment is greater than overturning moment

Partial factors on actions - Table A.3 - Combination 2

Permanent unfavourable action

$$\gamma_G = \mathbf{1.00}$$

Permanent favourable action

$$\gamma_{Gf} = \mathbf{1.00}$$

Variable unfavourable action

$$\gamma_Q = \mathbf{1.30}$$

Variable favourable action

$$\gamma_{Qf} = \mathbf{0.00}$$

Partial factors for soil parameters – Table A.4 - Combination 2

Angle of shearing resistance

$$\gamma_{\phi'} = \mathbf{1.25}$$

Effective cohesion

$$\gamma_{c'} = \mathbf{1.25}$$

Weight density

$$\gamma_{\gamma} = \mathbf{1.00}$$

Retained soil properties

Design moist density

$$\gamma_{mr}' = \gamma_{mr} / \gamma_{\gamma} = \mathbf{19 \text{ kN/m}^3}$$

Design saturated density

$$\gamma_{sr}' = \gamma_{sr} / \gamma_{\gamma} = \mathbf{21 \text{ kN/m}^3}$$

Design effective shear resistance angle

$$\phi'_{r,d} = \text{atan}(\tan(\phi'_{r,k}) / \gamma_{\phi'}) = \mathbf{24.8 \text{ deg}}$$

Design wall friction angle

$$\delta_{r,d} = \text{atan}(\tan(\delta_{r,k}) / \gamma_{\phi'}) = \mathbf{12.1 \text{ deg}}$$

Base soil properties

Design soil density

$$\gamma_b' = \gamma_b / \gamma_{\gamma} = \mathbf{18 \text{ kN/m}^3}$$

Design effective shear resistance angle

$$\phi'_{b,d} = \text{atan}(\tan(\phi'_{b,k}) / \gamma_{\phi'}) = \mathbf{24.8 \text{ deg}}$$

Design wall friction angle

$$\delta_{b,d} = \text{atan}(\tan(\delta_{b,k}) / \gamma_{\phi'}) = \mathbf{12.1 \text{ deg}}$$

Design base friction angle

$$\delta_{bb,d} = \text{atan}(\tan(\delta_{bb,k}) / \gamma_{\phi'}) = \mathbf{24.8 \text{ deg}}$$

Design effective cohesion

$$c'_{b,d} = c'_{b,k} / \gamma_{c'} = \mathbf{0 \text{ kN/m}^2}$$

Using Rankine theory

Active pressure coefficient

$$K_A = (1 - \sin(\phi'_{r,d})) / (1 + \sin(\phi'_{r,d})) = \mathbf{0.409}$$

Passive pressure coefficient

$$K_P = (1 + \sin(\phi'_{b,d})) / (1 - \sin(\phi'_{b,d})) = \mathbf{2.444}$$

Sliding check

Vertical forces on wall

Wall stem

$$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} = \mathbf{10.6 \text{ kN/m}}$$

Wall base

$$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} = \mathbf{8.1 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}' = \mathbf{5.9 \text{ kN/m}}$$

Base soil

$$F_{exc_v} = \gamma_{Gf} \times A_{exc} \times \gamma_b' = \mathbf{9.2 \text{ kN/m}}$$

Total

$$F_{total_v} = F_{stem} + F_{base} + F_{moist_v} + F_{exc_v} = \mathbf{33.8 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{sur_h} = K_A \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff} = \mathbf{14.4 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_h} = \gamma_G \times K_A \times \gamma_{mr}' \times h_{eff}^2 / 2 = \mathbf{12.6 \text{ kN/m}}$$

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Total

$$F_{\text{total}_h} = F_{\text{moist}_h} + F_{\text{sur}_h} = 27 \text{ kN/m}$$

Check stability against sliding

Base soil resistance

$$F_{\text{exc}_h} = \gamma_{\text{Gf}} \times K_P \times \gamma_b' \times (h_{\text{pass}} + h_{\text{base}})^2 / 2 = 15.9 \text{ kN/m}$$

Base friction

$$F_{\text{friction}} = F_{\text{total}_v} \times \tan(\delta_{\text{bb},d}) = 15.6 \text{ kN/m}$$

Resistance to sliding

$$F_{\text{rest}} = F_{\text{exc}_h} + F_{\text{friction}} = 31.5 \text{ kN/m}$$

Factor of safety

$$F_{\text{oS}_l} = F_{\text{rest}} / F_{\text{total}_h} = 1.169$$

PASS - Resistance to sliding is greater than sliding force

Overturning check

Vertical forces on wall

Wall stem

$$F_{\text{stem}} = \gamma_{\text{Gf}} \times A_{\text{stem}} \times \gamma_{\text{stem}} = 10.6 \text{ kN/m}$$

Wall base

$$F_{\text{base}} = \gamma_{\text{Gf}} \times A_{\text{base}} \times \gamma_{\text{base}} = 8.1 \text{ kN/m}$$

Moist retained soil

$$F_{\text{moist}_v} = \gamma_{\text{Gf}} \times A_{\text{moist}} \times \gamma_{\text{mr}}' = 5.9 \text{ kN/m}$$

Base soil

$$F_{\text{exc}_v} = \gamma_{\text{Gf}} \times A_{\text{exc}} \times \gamma_b' = 9.2 \text{ kN/m}$$

Total

$$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{moist}_v} + F_{\text{exc}_v} = 33.8 \text{ kN/m}$$

Horizontal forces on wall

Surcharge load

$$F_{\text{sur}_h} = K_A \times \gamma_Q \times \text{Surcharge}_Q \times h_{\text{eff}} = 14.4 \text{ kN/m}$$

Moist retained soil

$$F_{\text{moist}_h} = \gamma_{\text{G}} \times K_A \times \gamma_{\text{mr}}' \times h_{\text{eff}}^2 / 2 = 12.6 \text{ kN/m}$$

Base soil

$$F_{\text{exc}_h} = -\gamma_{\text{Gf}} \times K_P \times \gamma_b' \times (h_{\text{pass}} + h_{\text{base}})^2 / 2 = -15.9 \text{ kN/m}$$

Total

$$F_{\text{total}_h} = F_{\text{moist}_h} + F_{\text{exc}_h} + F_{\text{sur}_h} = 11.1 \text{ kN/m}$$

Overturning moments on wall

Surcharge load

$$M_{\text{sur}_{\text{OT}}} = F_{\text{sur}_h} \times X_{\text{sur}_h} = 12.9 \text{ kNm/m}$$

Moist retained soil

$$M_{\text{moist}_{\text{OT}}} = F_{\text{moist}_h} \times X_{\text{moist}_h} = 7.6 \text{ kNm/m}$$

Total

$$M_{\text{total}_{\text{OT}}} = M_{\text{moist}_{\text{OT}}} + M_{\text{sur}_{\text{OT}}} = 20.5 \text{ kNm/m}$$

Restoring moments on wall

Wall stem

$$M_{\text{stem}_R} = F_{\text{stem}} \times X_{\text{stem}} = 10.4 \text{ kNm/m}$$

Wall base

$$M_{\text{base}_R} = F_{\text{base}} \times X_{\text{base}} = 5.3 \text{ kNm/m}$$

Moist retained soil

$$M_{\text{moist}_R} = F_{\text{moist}_v} \times X_{\text{moist}_v} = 7.1 \text{ kNm/m}$$

Base soil

$$M_{\text{exc}_R} = F_{\text{exc}_v} \times X_{\text{exc}_v} - F_{\text{exc}_h} \times X_{\text{exc}_h} = 8.4 \text{ kNm/m}$$

Total

$$M_{\text{total}_R} = M_{\text{stem}_R} + M_{\text{base}_R} + M_{\text{moist}_R} + M_{\text{exc}_R} = 31.1 \text{ kNm/m}$$

Check stability against overturning

Factor of safety

$$F_{\text{O}_t} = M_{\text{total}_R} / M_{\text{total}_{\text{OT}}} = 1.519$$

PASS - Maximum restoring moment is greater than overturning moment

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 2.9.02

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

Concrete strength class

C32/40

Characteristic compressive cylinder strength

$$f_{\text{ck}} = 32 \text{ N/mm}^2$$

Characteristic compressive cube strength

$$f_{\text{ck,cube}} = 40 \text{ N/mm}^2$$

Mean value of compressive cylinder strength

$$f_{\text{cm}} = f_{\text{ck}} + 8 \text{ N/mm}^2 = 40 \text{ N/mm}^2$$

Mean value of axial tensile strength

$$f_{\text{ctm}} = 0.3 \text{ N/mm}^2 \times (f_{\text{ck}} / 1 \text{ N/mm}^2)^{2/3} = 3.0 \text{ N/mm}^2$$

5% fractile of axial tensile strength

$$f_{\text{ctk},0.05} = 0.7 \times f_{\text{ctm}} = 2.1 \text{ N/mm}^2$$

Secant modulus of elasticity of concrete

$$E_{\text{cm}} = 22 \text{ kN/mm}^2 \times (f_{\text{cm}} / 10 \text{ N/mm}^2)^{0.3} = 33346 \text{ N/mm}^2$$

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Partial factor for concrete - Table 2.1N

$$\gamma_C = 1.50$$

Compressive strength coefficient - cl.3.1.6(1)

$$\alpha_{cc} = 0.85$$

Design compressive concrete strength - exp.3.15

$$f_{cd} = \alpha_{cc} \times f_{ck} / \gamma_C = 18.1 \text{ N/mm}^2$$

Maximum aggregate size

$$h_{agg} = 20 \text{ mm}$$

Reinforcement details

Characteristic yield strength of reinforcement

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

Modulus of elasticity of reinforcement

$$E_s = 200000 \text{ N/mm}^2$$

Partial factor for reinforcing steel - Table 2.1N

$$\gamma_S = 1.15$$

Design yield strength of reinforcement

$$f_{yd} = f_{yk} / \gamma_S = 435 \text{ N/mm}^2$$

Cover to reinforcement

Front face of stem

$$c_{sf} = 40 \text{ mm}$$

Rear face of stem

$$c_{sr} = 50 \text{ mm}$$

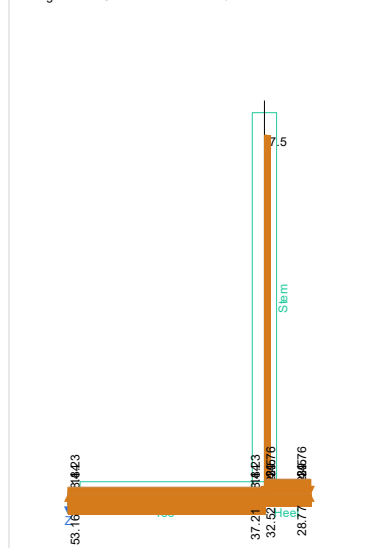
Top face of base

$$c_{bt} = 50 \text{ mm}$$

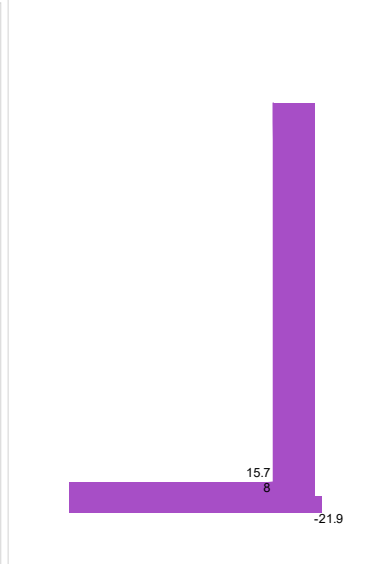
Bottom face of base

$$c_{bb} = 75 \text{ mm}$$

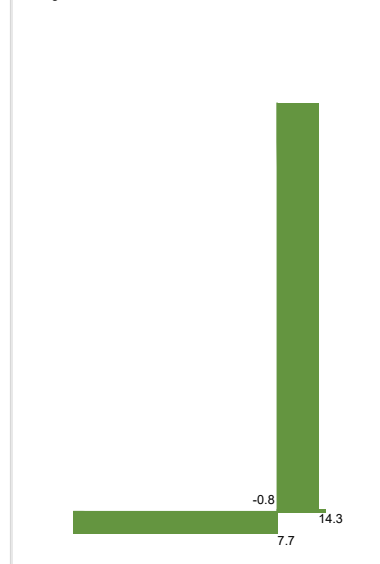
Loading details - Combination No.1 - kN/m²



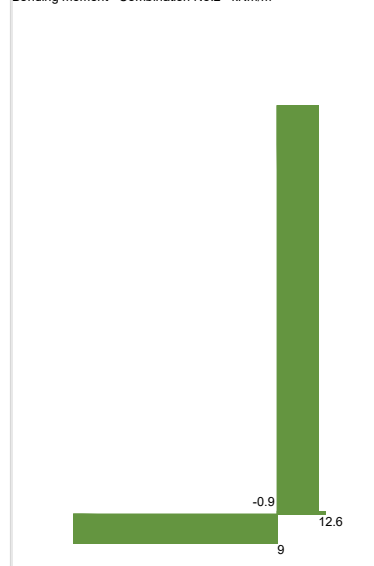
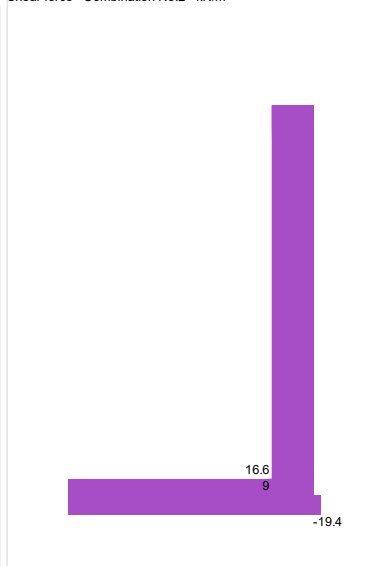
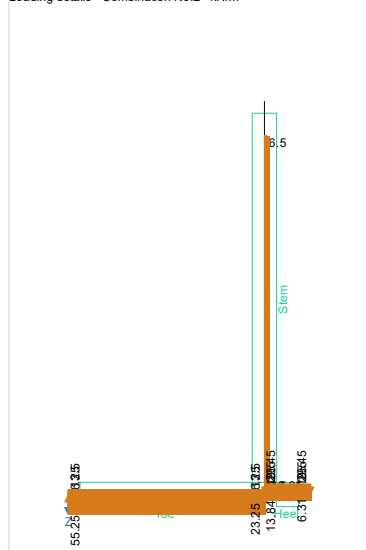
Shear force - Combination No.1 - kN/m



Bending moment - Combination No.1 - kNm/m



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Check stem design at base of stem

Depth of section

h = 250 mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 1

$$M = 14.3 \text{ kNm/m}$$

Depth to tension reinforcement

$$d = h - c_{sr} - \phi_{sr} / 2 = \mathbf{195 \text{ mm}}$$
$$K = M / (d^2 \times f_{ck}) = \mathbf{0.012}$$
 $K' = 0.207$

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

Lever arm

$$z = \min(0.5 + 0.5 \times (1 - 3.53 \times K)^{0.5}, 0.95) \times d = \mathbf{185 \text{ mm}}$$

Depth of neutral axis

$$x = 2.5 \times (d - z) = \mathbf{24 \text{ mm}}$$

Area of tension reinforcement required

$$A_{sr,req} = M / (f_{yd} \times z) = \mathbf{178 \text{ mm}^2/m}$$

Tension reinforcement provided

10 dia.bars @ 200 c/c

Area of tension reinforcement provided

$$A_{sr,prov} = \pi \times \phi_{sr}^2 / (4 \times s_{sr}) = \mathbf{393 \text{ mm}^2/m}$$

Minimum area of reinforcement - exp.9.1N

$$A_{s,r,min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = \mathbf{307 \text{ mm}^2/m}$$

Maximum area of reinforcement - cl.9.2.1.1(3)

$$A_{sr,max} = 0.04 \times h = \mathbf{10000} \text{ mm}^2/\text{m}$$
$$\max(A_{sr,reg}, A_{sr,min}) / A_{sr,prov} = 0.781$$

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

Deflection control - Section 7.4

Reference reinforcement ratio

$$\rho_0 = \sqrt[3]{(f_{ck} / 1 \text{ N/mm}^2) / 1000} = \mathbf{0.006}$$

Required tension reinforcement ratio

$$\rho = A_{sr.req} / d = \mathbf{0.001}$$

Required compression reinforcement ratio

$$\rho' = A_{\text{sr.2.reg}} / d_2 = \mathbf{0.000}$$

Structural system factor - Table 7.4N

$$K_b = 0.4$$

Reinforcement factor - exp.7.17

$$K_s = \min(500 \text{ N/mm}^2 / (f_{yk} \times A_{sr.req} / A_{sr.prov}), 1.5) = \mathbf{1.5}$$

Limiting span to depth ratio - exp.7.16.a

$$\min(K_s \times K_b \times [11 + 1.5 \times \sqrt{(f_{ck} / 1 \text{ N/mm}^2)} \times \rho_0 / \rho + 3.2 \times \sqrt{(f_{ck} / 1 \text{ N/mm}^2)} \times (\rho_0 / \rho - 1)^{3/2}], 40 \times K_b) = \mathbf{16}$$
$$h_{\text{stem}} / d = 8.7$$

PASS - Span to depth ratio is less than deflection control limit

Crack control - Section 7.3

Limiting crack width

$$W_{\max} = 0.3 \text{ mm}$$

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Variable load factor - EN1990 – Table A1.1

$$\psi_2 = 0.6$$

Serviceability bending moment

$$M_{sls} = 7.5 \text{ kNm/m}$$

Tensile stress in reinforcement

$$\sigma_s = M_{sls} / (A_{sr,prov} \times z) = 103.6 \text{ N/mm}^2$$

Load duration

Long term

Load duration factor

$$k_t = 0.4$$

Effective area of concrete in tension

$$A_{c,eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2) = 75208 \text{ mm}^2/\text{m}$$

Mean value of concrete tensile strength

$$f_{ct,eff} = f_{ctm} = 3.0 \text{ N/mm}^2$$

Reinforcement ratio

$$\rho_{p,eff} = A_{sr,prov} / A_{c,eff} = 0.005$$

Modular ratio

$$\alpha_e = E_s / E_{cm} = 5.998$$

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

$$s_{r,max} = k_3 \times c_{sr} + k_1 \times k_2 \times k_4 \times \phi_{sr} / \rho_{p,eff} = 496 \text{ mm}$$

Maximum crack width - exp.7.8

$$w_k = s_{r,max} \times \max(\sigma_s - k_t \times (f_{ct,eff} / \rho_{p,eff}) \times (1 + \alpha_e \times \rho_{p,eff}), 0.6 \times \sigma_s) / E_s$$

$$w_k = 0.154 \text{ mm}$$

$$w_k / w_{max} = 0.513$$

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force

$$V = 21.9 \text{ kN/m}$$

$$C_{Rd,c} = 0.18 / \gamma_c = 0.120$$

$$k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2) = 2.000$$

Longitudinal reinforcement ratio

$$\rho_l = \min(A_{sr,prov} / d, 0.02) = 0.002$$

$$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5} = 0.560 \text{ N/mm}^2$$

Design shear resistance - exp.6.2a & 6.2b

$$V_{Rd,c} = \max(C_{Rd,c} \times k \times (100 \text{ N}^2/\text{mm}^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$$

$$V_{Rd,c} = 109.2 \text{ kN/m}$$

$$V / V_{Rd,c} = 0.201$$

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)

$$A_{sx,req} = \max(0.25 \times A_{sr,prov}, 0.001 \times t_{stem}) = 250 \text{ mm}^2/\text{m}$$

Maximum spacing of reinforcement – cl.9.6.3(2)

$$s_{sx,max} = 400 \text{ mm}$$

Transverse reinforcement provided

$$10 \text{ dia.bars @ } 200 \text{ c/c}$$

Area of transverse reinforcement provided

$$A_{sx,prov} = \pi \times \phi_{sx}^2 / (4 \times s_{sx}) = 393 \text{ mm}^2/\text{m}$$

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

Check base design at toe

Depth of section

$$h = 250 \text{ mm}$$

Rectangular section in flexure - Section 6.1

Design bending moment combination 2

$$M = 9 \text{ kNm/m}$$

Depth to tension reinforcement

$$d = h - c_{bb} - \phi_{bb} / 2 = 170 \text{ mm}$$

$$K = M / (d^2 \times f_{ck}) = 0.010$$

$$K' = 0.207$$

K' > K - No compression reinforcement is required

Lever arm

$$z = \min(0.5 + 0.5 \times (1 - 3.53 \times K)^{0.5}, 0.95) \times d = 161 \text{ mm}$$

Depth of neutral axis

$$x = 2.5 \times (d - z) = 21 \text{ mm}$$

Area of tension reinforcement required

$$A_{bb,req} = M / (f_{yd} \times z) = 128 \text{ mm}^2/\text{m}$$

Tension reinforcement provided

$$10 \text{ dia.bars @ } 200 \text{ c/c}$$

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Area of tension reinforcement provided

$$A_{bb,prov} = \pi \times \phi_{bb}^2 / (4 \times s_{bb}) = \mathbf{393 \text{ mm}^2/m}$$

Minimum area of reinforcement - exp.9.1N

$$A_{bb,min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = \mathbf{267 \text{ mm}^2/m}$$

Maximum area of reinforcement - cl.9.2.1.1(3)

$$A_{bb,max} = 0.04 \times h = \mathbf{10000 \text{ mm}^2/m}$$

$$\max(A_{bb,req}, A_{bb,min}) / A_{bb,prov} = \mathbf{0.681}$$

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

Crack control - Section 7.3

Limiting crack width

$$w_{max} = \mathbf{0.3 \text{ mm}}$$

Variable load factor - EN1990 – Table A1.1

$$\psi_2 = \mathbf{0.6}$$

Serviceability bending moment

$$M_{sls} = \mathbf{5.2 \text{ kNm/m}}$$

Tensile stress in reinforcement

$$\sigma_s = M_{sls} / (A_{bb,prov} \times z) = \mathbf{82.6 \text{ N/mm}^2}$$

Load duration

Long term

Load duration factor

$$k_t = \mathbf{0.4}$$

Effective area of concrete in tension

$$A_{c,eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2) = \mathbf{76250 \text{ mm}^2/m}$$

Mean value of concrete tensile strength

$$f_{ct,eff} = f_{ctm} = \mathbf{3.0 \text{ N/mm}^2}$$

Reinforcement ratio

$$\rho_{p,eff} = A_{bb,prov} / A_{c,eff} = \mathbf{0.005}$$

Modular ratio

$$\alpha_e = E_s / E_{cm} = \mathbf{5.998}$$

Bond property coefficient

$$k_1 = \mathbf{0.8}$$

Strain distribution coefficient

$$k_2 = \mathbf{0.5}$$

$$k_3 = \mathbf{3.4}$$

$$k_4 = \mathbf{0.425}$$

Maximum crack spacing - exp.7.11

$$s_{r,max} = k_3 \times c_{bb} + k_1 \times k_2 \times k_4 \times \phi_{bb} / \rho_{p,eff} = \mathbf{585 \text{ mm}}$$

Maximum crack width - exp.7.8

$$w_k = s_{r,max} \times \max(\sigma_s - k_t \times (f_{ct,eff} / \rho_{p,eff}) \times (1 + \alpha_e \times \rho_{p,eff}), 0.6 \times \sigma_s) / E_s$$

$$w_k = \mathbf{0.145 \text{ mm}}$$

$$w_k / w_{max} = \mathbf{0.483}$$

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force

$$V = \mathbf{16.6 \text{ kN/m}}$$

$$C_{Rd,c} = 0.18 / \gamma_c = \mathbf{0.120}$$

$$k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2) = \mathbf{2.000}$$

Longitudinal reinforcement ratio

$$\rho_l = \min(A_{bb,prov} / d, 0.02) = \mathbf{0.002}$$

$$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5} = \mathbf{0.560 \text{ N/mm}^2}$$

Design shear resistance - exp.6.2a & 6.2b

$$V_{Rd,c} = \max(C_{Rd,c} \times k \times (100 \text{ N}^2/\text{mm}^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$$

$$V_{Rd,c} = \mathbf{95.2 \text{ kN/m}}$$

$$V / V_{Rd,c} = \mathbf{0.174}$$

PASS - Design shear resistance exceeds design shear force

Check base design at heel

Depth of section

$$h = \mathbf{250 \text{ mm}}$$

Rectangular section in flexure - Section 6.1

Design bending moment combination 2

$$M = \mathbf{0.9 \text{ kNm/m}}$$

Depth to tension reinforcement

$$d = h - c_{bt} - \phi_{bt} / 2 = \mathbf{195 \text{ mm}}$$

$$K = M / (d^2 \times f_{ck}) = \mathbf{0.001}$$

$$K' = \mathbf{0.207}$$

K' > K - No compression reinforcement is required

Lever arm

$$z = \min(0.5 + 0.5 \times (1 - 3.53 \times K)^{0.5}, 0.95) \times d = \mathbf{185 \text{ mm}}$$

Depth of neutral axis

$$x = 2.5 \times (d - z) = \mathbf{24 \text{ mm}}$$

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Area of tension reinforcement required $A_{bt.req} = M / (f_{yd} \times z) = 12 \text{ mm}^2/\text{m}$
 Tension reinforcement provided 10 dia.bars @ 200 c/c
 Area of tension reinforcement provided $A_{bt.prov} = \pi \times \phi_{bt}^2 / (4 \times s_{bt}) = 393 \text{ mm}^2/\text{m}$
 Minimum area of reinforcement - exp.9.1N $A_{bt.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = 307 \text{ mm}^2/\text{m}$
 Maximum area of reinforcement - cl.9.2.1.1(3) $A_{bt.max} = 0.04 \times h = 10000 \text{ mm}^2/\text{m}$
 $\max(A_{bt.req}, A_{bt.min}) / A_{bt.prov} = 0.781$

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

Crack control - Section 7.3

Limiting crack width $w_{max} = 0.3 \text{ mm}$
 Variable load factor - EN1990 – Table A1.1 $\psi_2 = 0.6$
 Serviceability bending moment $M_{sls} = 0.4 \text{ kNm/m}$
 Tensile stress in reinforcement $\sigma_s = M_{sls} / (A_{bt.prov} \times z) = 5.8 \text{ N/mm}^2$
 Load duration Long term
 Load duration factor $k_t = 0.4$
 Effective area of concrete in tension $A_{c.eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2) = 75208 \text{ mm}^2/\text{m}$
 Mean value of concrete tensile strength $f_{ct.eff} = f_{ctm} = 3.0 \text{ N/mm}^2$
 Reinforcement ratio $\rho_{p.eff} = A_{bt.prov} / A_{c.eff} = 0.005$
 Modular ratio $\alpha_e = E_s / E_{cm} = 5.998$
 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 $s_{r,max} = k_3 \times c_{bt} + k_1 \times k_2 \times k_4 \times \phi_{bt} / \rho_{p.eff} = 496 \text{ mm}$
 Maximum crack width - exp.7.8 $w_k = s_{r,max} \times \max(\sigma_s - k_t \times (f_{ct.eff} / \rho_{p.eff}) \times (1 + \alpha_e \times \rho_{p.eff}), 0.6 \times \sigma_s) / E_s$
 $w_k = 0.009 \text{ mm}$
 $w_k / w_{max} = 0.029$

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force $V = 9 \text{ kN/m}$
 $C_{Rd,c} = 0.18 / \gamma_c = 0.120$
 $k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2) = 2.000$
 Longitudinal reinforcement ratio $\rho_l = \min(A_{bt.prov} / d, 0.02) = 0.002$
 $v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5} = 0.560 \text{ N/mm}^2$
 Design shear resistance - exp.6.2a & 6.2b $V_{Rd,c} = \max(C_{Rd,c} \times k \times (100 \text{ N}^2/\text{mm}^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$
 $V_{Rd,c} = 109.2 \text{ kN/m}$
 $V / V_{Rd,c} = 0.083$

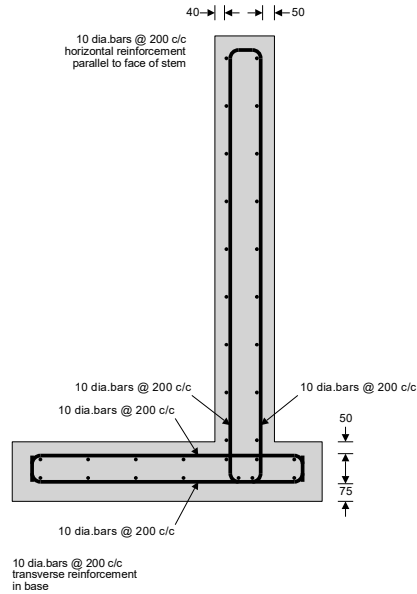
PASS - Design shear resistance exceeds design shear force

Secondary transverse reinforcement to base - Section 9.3

Minimum area of reinforcement – cl.9.3.1.1(2) $A_{bx.req} = 0.2 \times A_{bt.prov} = 79 \text{ mm}^2/\text{m}$
 Maximum spacing of reinforcement – cl.9.3.1.1(3) $s_{bx,max} = 450 \text{ mm}$
 Transverse reinforcement provided 10 dia.bars @ 200 c/c
 Area of transverse reinforcement provided $A_{bx.prov} = \pi \times \phi_{bx}^2 / (4 \times s_{bx}) = 393 \text{ mm}^2/\text{m}$

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

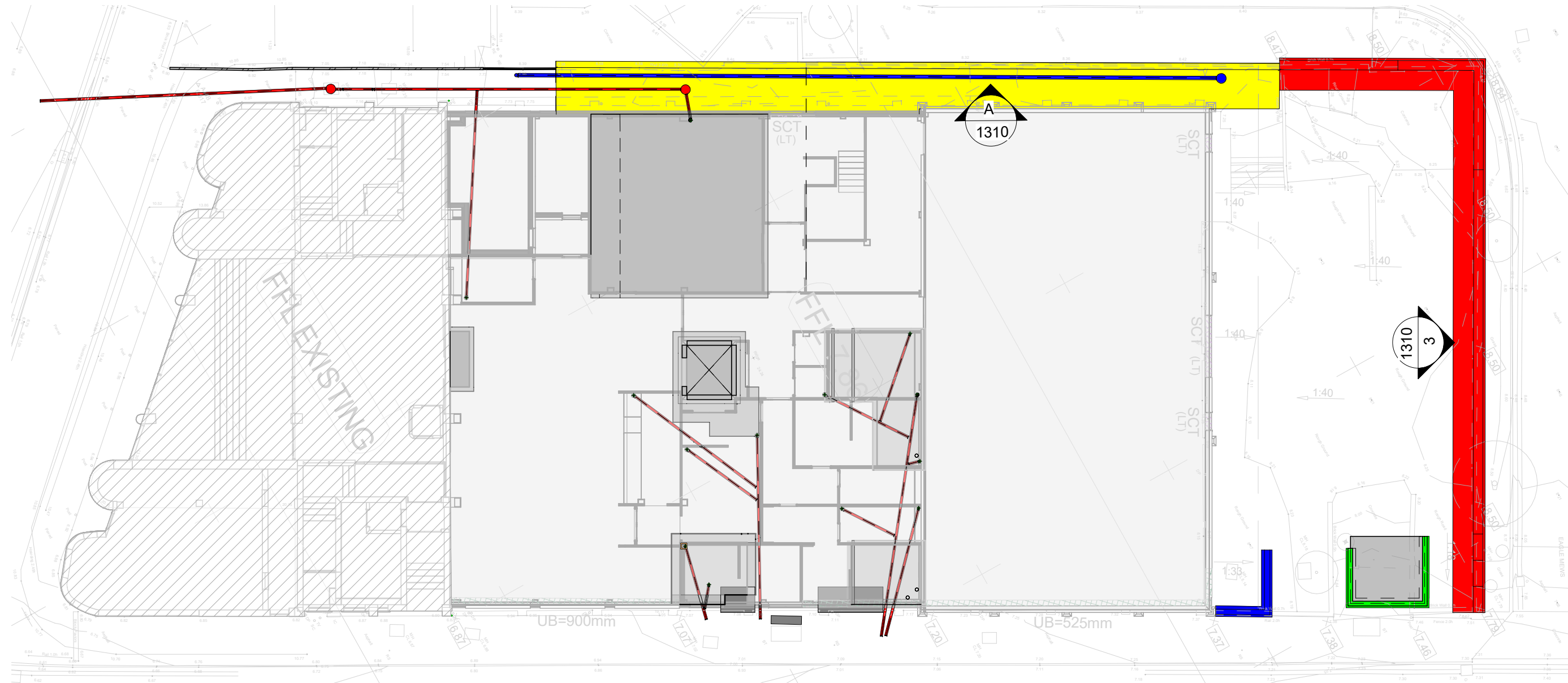
Project				Job no.	
Port Talbot Plaza					
Calcs for				Start page no./Revision	
Retaining Wall - Stem reinforcement check				12	
Calcs by	Calcs date	Checked by	Checked date	Approved by	Approved date
PJ	23/02/2021				



Reinforcement details

Appendix C - Drawing

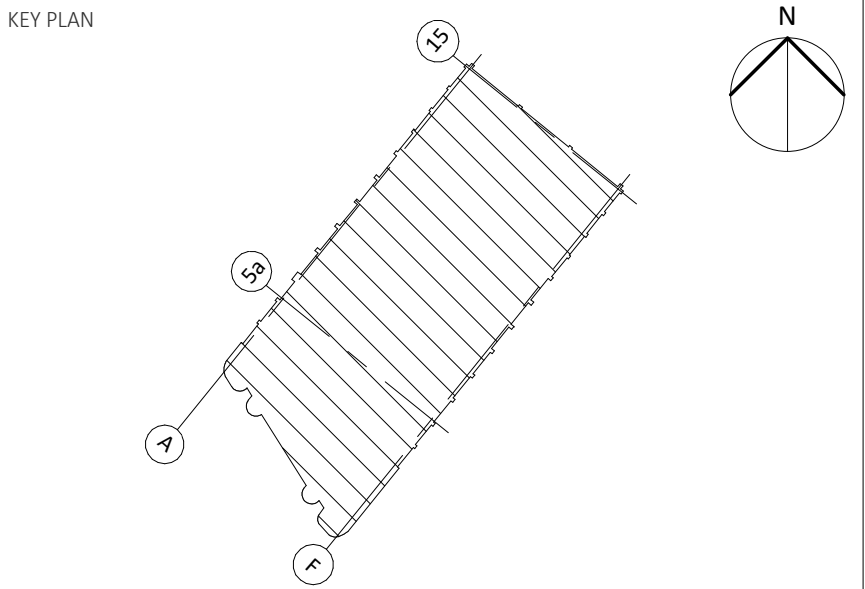
18/01/2021 15:42:58 F:\01 Contracts\0000-CC-C-10892 - Port Talbot Phase Redevelopment\01_WP\W3_Model_3d\5\PT-HYD-XX-ZZ-M3-S-0001_2019_P7 6 new wall.rvt



1310.01 - RETAINING WALL KEY PLAN

1 : 200

- KEY:
- MASONRY RETAINING WALL SEE DETAIL 1
 - CAVITY FILLED MASONRY RETAINING WALL SEE DETAIL 2
 - RC RETAINING WALL WITH MASONRY FINISH SEE DETAIL 3
 - RC RETAINING WALL SEE DETAIL 4



NOTES

- ALL DIMENSIONS ARE TO BE CHECKED ON SITE BEFORE THE COMMENCEMENT OF WORKS. ANY DISCREPANCIES ARE TO BE REPORTED TO THE ARCHITECT & ENGINEER FOR VERIFICATION. FIGURED DIMENSIONS ONLY ARE TO BE TAKEN FROM THIS DRAWING.
- THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ALL RELEVANT ENGINEERS' AND SERVICE ENGINEERS' DRAWINGS AND SPECIFICATIONS. THIS DRAWING IS COPYRIGHT.

FOUNDATIONS

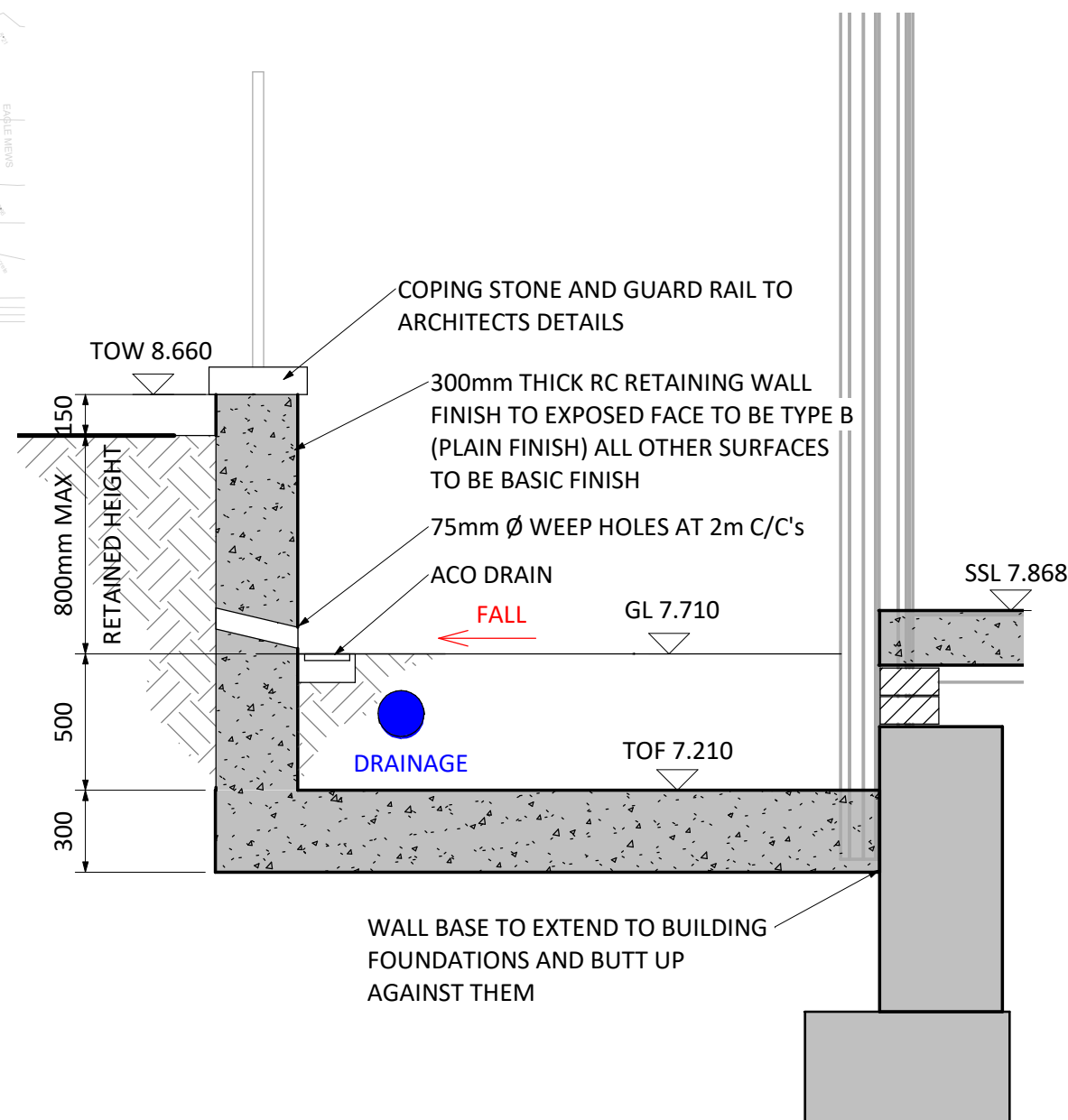
- ALL EXCAVATIONS FOR FOUNDATIONS TO BE BLINDED 50mm LEAN-MIX CONCRETE OR 50mm COMPACTED SAND.

CONCRETE

- MASS FILL CONCRETE TO BE MIN GRADE FND2
- REINFORCED CONCRETE TO BE GRADE C32/C40

MASONRY

- ALL BELOW GROUND BLOCKWORK TO BE MEDIUM-DENSE, MIN STRENGTH 7.3N/mm².
- ALL BELOW GROUND BRICKWORK TO BE MIN CLASS B ENGINEERING BRICK.
- ALL ABOVE GROUND BRICKWORK TO ARCHITECTS SPECIFICATION.
- ALL MORTAR TO BE MINIMUM M4.



1310.05 - DETAIL 4 SECTION THROUGH RC RETAINING WALL

1 : 25

REVISIONS

REV	DRAWN BY	DATE	CHECKED BY	DATE	APPROVED BY	DATE
C01						
L BUSHROD	18/01/21	P DAVIES	18/01/21	M ACE	18/01/21	
P01						
L BUSHROD	18/10/19	P DAVIES	18/10/19	M ACE	18/10/19	
REV	REVISION NOTES/COMMENTS					

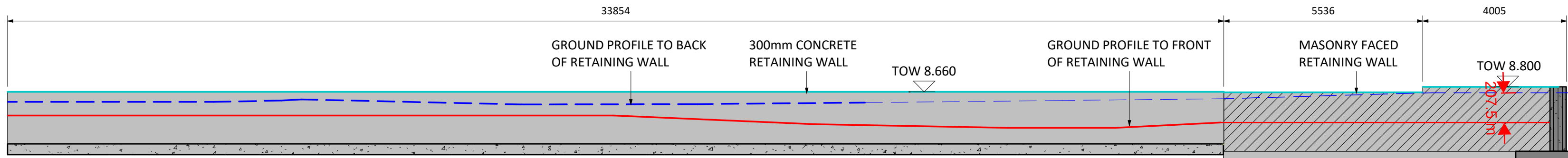
Hydrock Castlebridge 5
5-19 Cowbridge Road East
CARDIFF
CF11 9AB
t: +44(0)2920 023665
e: cardiff@hydrock.com

CLIENT
NEATH PORT TALBOT COUNTY BOROUGH COUNCIL

PROJECT
PLAZA PORT TALBOT

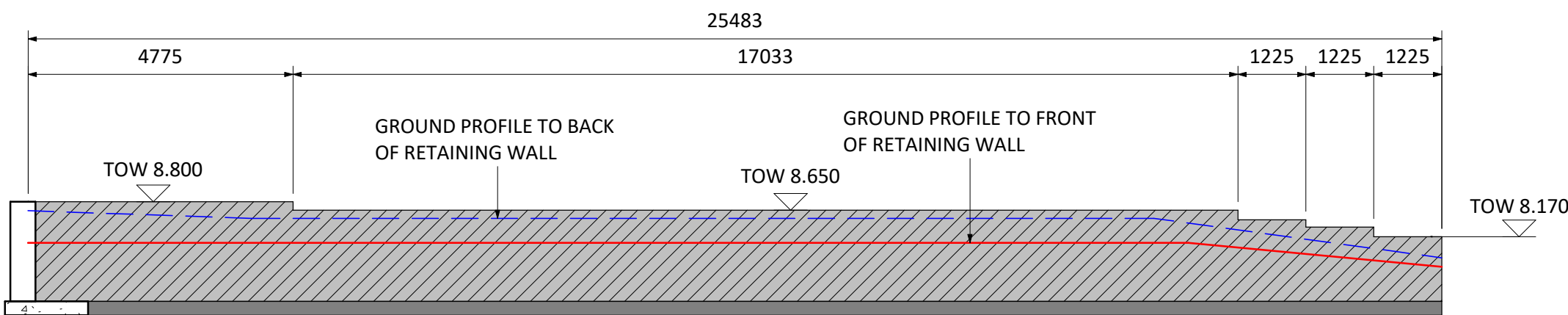
TITLE
EXTERNAL RETAINING WALL DETAILS

HYDROCK PROJECT NO. C-10892	SCALE @ A1 As indicated
SUITABILITY DESCRIPTION CONSTRUCTION (FULL APPROVAL)	SUITABILITY A1
DRAWING NO. (PROJECT - ORIGINATOR - VOLUME - LEVEL - TYPE - ROLE - NUMBER) PPT-HYD-XX-ZZ-DR-S-1310	REVISION C01



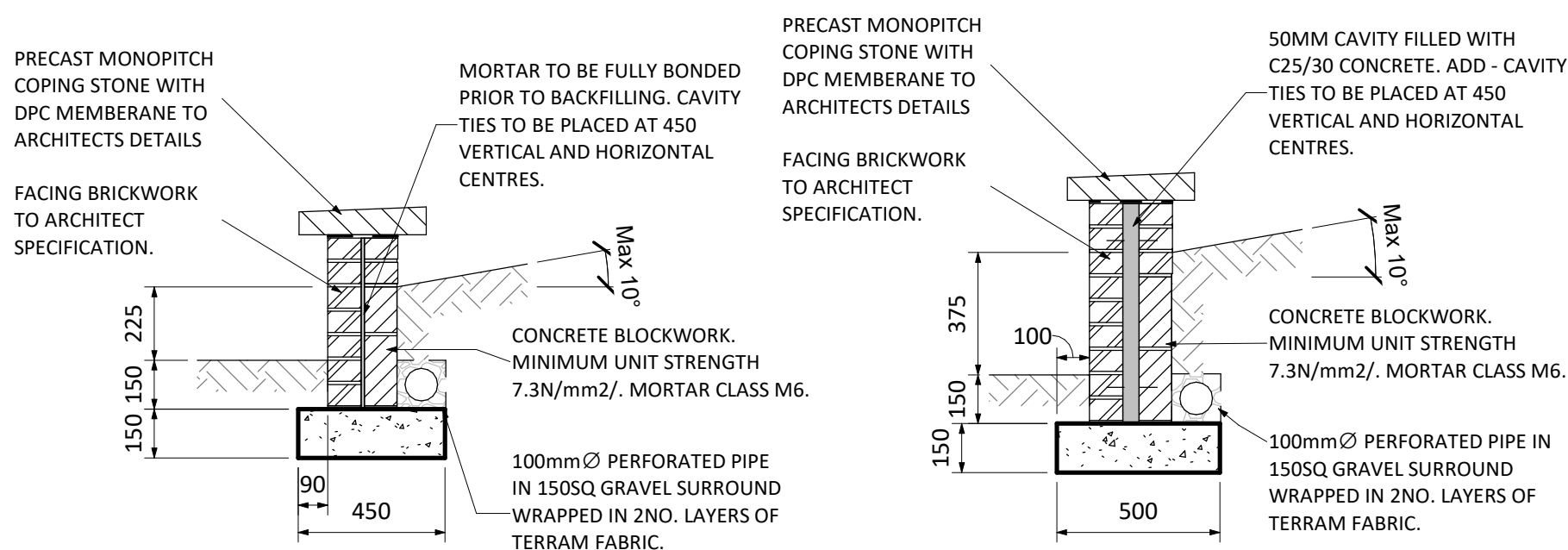
1310.02 - ELEVATION A

1 : 100

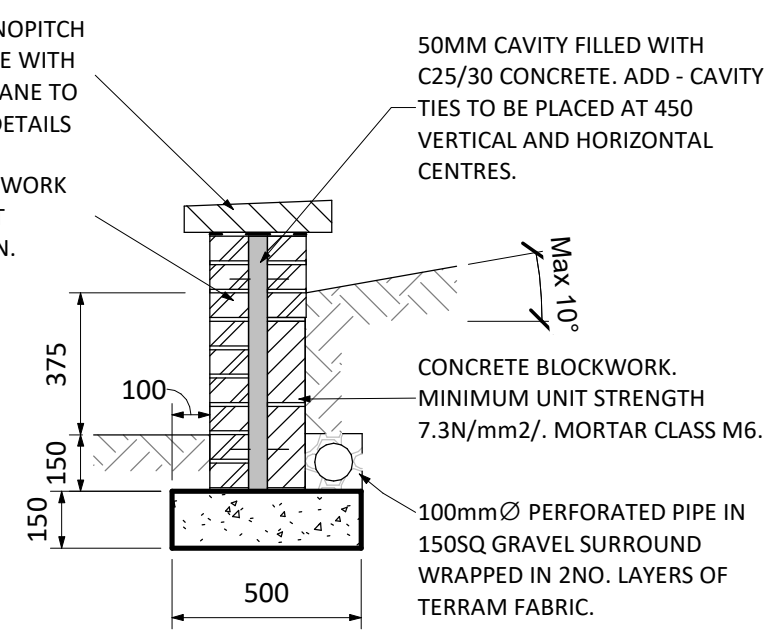


1310.03 - ELEVATION B

1 : 100



DETAIL 1 CAVITY FILL RETAINING WALL
MAXIMUM RETAINED HEIGHT 225mm
[MAXIMUM SUCHARGE 5kPa]



DETAIL 2 CAVITY FILL RETAINING WALL
MAXIMUM RETAINED HEIGHT 375mm
[MAXIMUM SUCHARGE 5kPa]

NOTE:

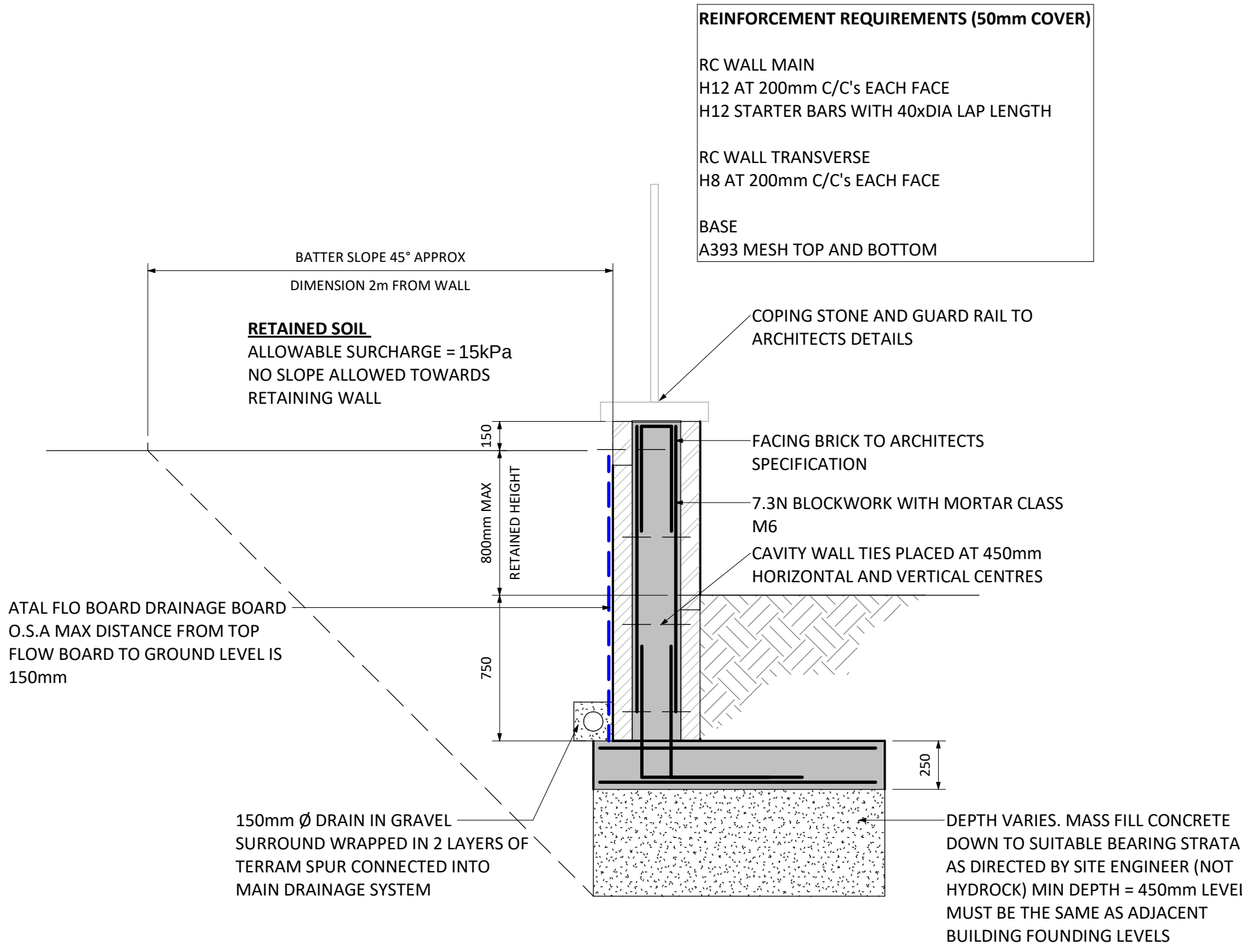
WEEPHOLES/WATERPROOFING TO CONTRACTORS SPECIFICATION TO REFLECT CLIENT REQUIREMENTS.

DESIGN BASED ON ALLOWABLE BEARING PRESSURE OF 100kN/m².

FOUNDING MATERIAL TO BE PROOF ROLLED AND PLATE TESTED TO CONFIRM MINIMUM ALLOWABLE BEARING PRESSURE HAS BEEN ACHIEVED PRIOR TO CONSTRUCTION.

FOUNDING MATERIAL WILL VARY ACROSS THE SITE

ALL VISIBLE SOFT SPOTS BELOW PROPOSED FOUNDATIONS TO BE EXCAVATED AND REPLACED WITH COMPACTED GRANULAR FILL PRIOR TO PROOF ROLLING AND PLATE TESTING OF GROUND.



1310.04 - DETAIL 3 SECTION THROUGH MASONRY FACED RC RETAINING WALL

1 : 25