RC Column design

In accordance with EN1992-1-1:2004 incorporating Corrigendum January 2008 and the UK national annex

Tedds calculation version 1.2.15

8 no. 20 mm diameter longitudinal bars
10 mm diameter links
Max link spacing 200 mm generally, 120 mm for 200 mm above and below slab/beam and at laps

Column geometry

Overall depth (perp y); h = 200 mm
Clear ht bet restr about y axis; l_y = 2800 mm
Stability in the y direction; Braced

Overall breadth (perp z); b = 500 mm
Clear ht bet restr about z axis; l_z = 2800 mm
Stability in the y direction; Braced

Concrete details

Cylinder strength of concrete; f_{ck} = 32 MPa
Safety factor for concrete; \gamma_C = 1.50
Coefficient \alpha_{cc}; \alpha_{cc} = 0.85
Maximum aggregate size; d_g = 20 mm

Reinforcement details

Nominal cover to links; c_{nom} = 35 mm
Longitudinal bar diameter; \phi = 20 mm
Link diameter; \phi_l = 10 mm
Total no. of longitudinal bars; N = 8
No. bars per face parallel y axis; N_y = 4
No. bars per face parallel z axis; N_z = 2
Area of longitudinal reinft; A_s = 2513 mm^2
Safety factor for reinforcement; \gamma_S = 1.15
Modulus of elasticity of reinft; E_s = 200000 MPa

Fire resistance details

Fire resistance period; R = 60 min
Ratio of fire design axial load to design resistance; \psi = 0.70

Exposure to fire; Exposed one side only

Axial load and bending moments from frame analysis

Design axial load; N_{Ed} = 700.0 kN
Moment about y axis at top; M_{Edy} = 35.0 kNm
Moment about z axis at top; M_{Edz} = 35.0 kNm

Column end restraints

End restraints buckling abt y; Braced, no rotational restraint both ends
End restraints buckling abt z; Braced, no rotational restraint both ends

Check nominal cover for fire and bond requirements

Min cover to links for bond; c_{min,b} = 10 mm
Min cover to links for fire; c_{min,fi} = 15.0 mm
Min allowable nominal cover; c_{nom, min} = 15.0 mm

PASS - the nominal cover is greater than the minimum required

Check end distance and slenderness

Min distance for fire; a_f = 25 mm

Min allowable end distance; a_{min} = 5 mm

Column slenderness

L_y = 48.5; \lambda_y = 19.4
L_z = 23.4; \lambda_z = 23.4

Design bending moments

Design moment about y axis; M_{Edy} = 65.1 kNm
Design moment about z axis; M_{Edz} = 99.9 kNm

Biaxial bending

Exponent a; a = 1.12

Key points on interaction diagram for bending about y axis

Axial load capacity no mt; N_{Ed,b} = 2647 kN
Axial no strain in tension reinft; N_{Ed,t} = 1575 kN
Axial conc/tension steel at yield N_{Ed,y} = 418 kN

Braced, no rotational restraint both ends

Axial conc/tension steel at yield; N_{Ed,y} = 418 kN
M_{Ed,y} = 67.7 kNm
M_{Ed,z} = 80.5 kNm
Axial at additional location: $N_{Rd4} = 1991 \text{ kN}$; 
Mt capacity no axial load: $M_{Rd3} = 62.6 \text{ kNm}$

Key points on interaction diagram for bending about z axis
Axial load capacity no mt: $N_{Rd6} = 2647 \text{ kN}$
Axial no strain in tension reinft: $N_{Rdz1} = 1916 \text{ kN}$; 
Mt no strain in tension reinft: $M_{Rdz1} = 152.4 \text{ kNm}$
Axial conc/tension steel at yield: $N_{Rdz2} = 852 \text{ kN}$; 
Mt conc/tension steel at yield: $M_{Rdz2} = 228.8 \text{ kNm}$
Axial at additional location: $N_{Rdz4} = 2361 \text{ kN}$; 
Mt at additional location: $M_{Rdz4} = 88.1 \text{ kNm}$

Interaction diagram for bending about y axis
200 mm x 500 mm column, 8 no. 20 mm longitudinal bars

Interaction diagram for bending about z axis
200 mm x 500 mm column, 8 no. 20 mm longitudinal bars
**RC wall design**

In accordance with EN1992-1-1:2004 incorporating corrigendum January 2008 and the UK national annex

Tedds calculation version 1.0.09

Wall geometry

- Thickness; \( h = 200 \) mm
- Length; \( b = 1000 \) mm/m
- Stability about minor axis; Unbraced

Concrete details

- Concrete strength class; \( \text{C}32/40 \)
- Safety factor for concrete; \( \gamma_c = 1.50 \)
- Coefficient \( \alpha_{cc} \); \( \alpha_{cc} = 0.85 \)
- Maximum aggregate size; \( d_g = 20 \) mm

Reinforcement details

- Reinforcement in outer layer; Vertical
  - Vertical bar diameter; \( \phi_v = 16 \) mm
  - Spacing of vertical reinft; \( s_v = 200 \) mm
- Area of vertical reinft (per face); \( A_{sv} = 1005 \) mm²/m
- Partial safety factor for reinft; \( \gamma_S = 1.15 \)
- Modulus of elasticity of reinft; \( E_s = 200000 \) MPa

Reinforcement in outer layer; Horizontal
- Horizontal bar diameter; \( \phi_h = 10 \) mm
- Spacing of horizontal reinft; \( s_h = 250 \) mm
- Area of horiz. reinft (per face); \( A_{sh} = 314 \) mm²/m

Fire resistance details

- Fire resistance period; \( R = 60 \) min
- Exposure to fire; Exposed on two sides
- Ratio of fire design axial load to design resistance; \( \mu_f = 0.50 \)

Axial load and bending moments from frame analysis

- Design axial load; \( N_{Ed} = 280.0 \) kN/m
- Mt about minor axis at top; \( M_{ttop} = 10.0 \) kNm/m
- Mt about minor axis at bottom; \( M_{tbtm} = 10.0 \) kNm/m

Wall end restraints

- Unbraced, rotational restraint both ends

Check nominal cover for fire and bond requirements

- Min. cover reqd for bond; \( c_{nom, reb} = 16 \) mm
- Min axis distance for fire; \( a_v = 10 \) mm
- Min allowable nominal cover; \( c_{nom, min} = 21.0 \) mm

**PASS - the nominal cover is greater than the minimum required**

Wall slenderness

- Slenderness ratio; \( \lambda = 58.9 \)
- Slenderness limit; \( \lambda_{lim} = 42.9 \)

**\( \lambda > \lambda_{lim} \) - Second order effects must be considered**

Design bending moment

- Design mt about minor axis; \( M_{Ed} = 24.4 \) kNm/m

Key points on interaction diagram for bending about minor axis

- Axial compression cap. no mt; \( N_{Ed} = 4294 \) kN/m
- Axial no strain in tension reinft; \( N_{h} = 2769 \) kN/m
- Mt conc/tension steel at yield; \( M_{t} = 1430 \) kNm/m
- Axial no strain in tension reinft; \( N_{h} = 108.7 \) kN/mm
- Mt conc/tension steel at yield; \( M_{t} = 140.0 \) kNm/m
- Axial no strain in tension reinft; \( N_{h} = 66.1 \) kNm/m
- Mt at additional location; \( M_{t} = 74.3 \) kNm/m
Retaining wall analysis - FRONT RETAINING WALL AS PROPPED

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; Propped cantilever
Stem height; \( h_{stem} = 2800 \text{ mm} \)
Prop height; \( h_{prop} = 2650 \text{ mm} \)
Angle to rear face of stem; \( \alpha = 90 \text{ deg} \)
Stem thickness; \( t_{stem} \)
Angle to rear face of stem; \( \alpha = 90 \text{ deg} \)
Stem density; \( \gamma_{stem} \)
Prop height; \( h_{prop} = 250 \text{ mm} \)
Base thickness; \( t_{base} = 450 \text{ mm} \)
Base thickness; \( t_{base} \)
Height of retained soil; \( h_{ret} = 2600 \text{ mm} \)
Angle of soil surface; \( \beta = 0 \text{ deg} \)
Depth of cover; \( d_{cover} = 0 \text{ mm} \)
Height of water; \( h_{water} \)
Base density; \( \gamma_{base} \)

Retained soil properties
Soil type; Medium dense well graded sand and gravel
Moist density; \( \gamma_{w} \)
Saturated density; \( \gamma_{s} \)
Characteristic effective shear resistance angle; \( \varphi'_s = 35 \text{ deg} \)
Characteristic wall friction angle; \( \delta_s = 17.5 \text{ deg} \)

Base soil properties
Soil density; \( \gamma_{b} \)
Characteristic effective shear resistance angle; \( \varphi'_b = 30 \text{ deg} \)
Characteristic wall friction angle; \( \delta_b = 15 \text{ deg} \)
Characteristic base friction angle; \( \delta_{b,b} = 20 \text{ deg} \)
Presumed bearing capacity; \( P_{base,r} = 125 \text{ kN/m}^2 \)

Loading details
Permanent surcharge load; \( S_{sur} = 5 \text{ kN/m}^2 \)
Variable surcharge load; \( S_{var} = 20 \text{ kN/m}^2 \)
Vertical load at 2150 mm; \( P_{v1} = 100 \text{ kN/m} \)
\( P_{v2} = 25 \text{ kN/m} \)

Calculate retaining wall geometry
Base length; \( L_{base} = 2250 \text{ mm} \)
Saturated soil height; \( h_{sat} = 1600 \text{ mm} \)
Moist soil height; \( h_{moist} = 1000 \text{ mm} \)
Length of surcharge load; \( l_{sur} = 0 \text{ mm} \)
Vertical distance; \( x_{stem_v} = 2250 \text{ mm} \)
Effective height of wall; \( h_{eff} = 3050 \text{ mm} \)
Horizontal distance; \( x_{stem_h} = 1525 \text{ mm} \)
Area of wall stem; \( A_{stem,b} = 0.7 \text{ m}^2 \)
Vertical distance; \( x_{stem} = 2125 \text{ mm} \)
Area of wall base; \( A_{base,b} = 1.013 \text{ m}^2 \)
Vertical distance; \( x_{base} = 1125 \text{ mm} \)

Using Coulomb theory
Active pressure coefficient; \( K_a = 0.246 \)
Passive pressure coefficient; \( K_p = 4.977 \)

Bearing pressure check
Vertical forces on wall Total; \( F_{v,tot} = F_{v,stem} + F_{v,base} + F_{v,sur} + F_{v,water} = 167.8 \text{ kN/m} \)
Horizontal forces on wall Total; \( F_{h,tot} = F_{h,stem} + F_{h,base} + F_{h,sur} + F_{h,water} = 47.5 \text{ kN/m} \)
Moments on wall
Total: \[ M_{\text{total}} = M_{\text{stem}} + M_{\text{base}} + M_{\text{sat}} + M_{\text{moist}} + M_{\text{water}} + M_{\text{sur}} + M_{\text{P}} = 272.6 \text{kN/m} \]

Check bearing pressure
Propping force to stem; \[ F_{\text{prop, stem}} = -27 \text{kN/m} \]
Bearing pressure at toe; \[ q_{\text{toe}} = 74.6 \text{kN/m}^2 \]
Bearing pressure at heel; \[ q_{\text{heel}} = 74.6 \text{kN/m}^2 \]
Factor of safety; \[ F_{\text{OS}} = 1.676 \]
PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

RE蒂TING WALL DESIGN

Concrete details - Table 3.1 - Strength and deformation characteristics for concrete
Concrete strength class; \[ C32/40 \]
Char. comp. cylinder strength; \[ f_{\text{ck}} = 32 \text{N/mm}^2 \]
Secant modulus of elasticity; \[ E_s = 33346 \text{N/mm}^2 \]
Design comp. concrete strength; \[ f_{\text{cd}} = 18.1 \text{N/mm}^2 \]

Reinforcement details
Characteristic yield strength; \[ f_{\text{yk}} = 500 \text{N/mm}^2 \]
Modulus of elasticity; \[ E_s = 200000 \text{N/mm}^2 \]

Cover to reinforcement
Front face of stem; \[ c_{\text{sf}} = 30 \text{mm} \]
Rear face of stem; \[ c_{\text{sr}} = 50 \text{mm} \]
Top face of base; \[ c_{\text{bt}} = 30 \text{mm} \]
Bottom face of base; \[ c_{\text{bb}} = 50 \text{mm} \]
Check stem design at 1499 mm
Depth of section; h = 250 mm
Rectangular section in flexure - Section 6.1
Design bending moment; M = 8.9 kNm/m; K = 0.007; K' = 0.207
Tens.reinforcement required; A_{sr,req} = 106 mm$^2$/m
Tens.reinforcement provided; 12 dia.bars @ 200 c/c; Tens.reinforcement provided; A_{sr,prov} = 565 mm$^2$/m
Min.area of reinforcement; A_{sr,min} = 321 mm$^2$/m; Max.area of reinforcement; A_{sr,max} = 10000 mm$^2$/m
PASS - Area of reinforcement provided is greater than area of reinforcement required

Deflection control - Section 7.4
Limiting span to depth ratio; 40 Actual span to depth ratio; 13
PASS - Span to depth ratio is less than deflection control limit

Crack control - Section 7.3
Limiting crack width; w_{c,max} = 0.3 mm; Maximum crack width; w_a = 0.056 mm
PASS - Maximum crack width is less than limiting crack width

Check stem design at base of stem
Depth of section; h = 250 mm
Rectangular section in flexure - Section 6.1
Design bending moment; M = 19.9 kNm/m; K = 0.016; K' = 0.207
Tens.reinforcement required; A_{sr,req} = 248 mm$^2$/m
Tens.reinforcement provided; 12 dia.bars @ 200 c/c; Tens.reinforcement provided; A_{sr,prov} = 565 mm$^2$/m
Min.area of reinforcement; A_{sr,min} = 305 mm$^2$/m; Max.area of reinforcement; A_{sr,max} = 10000 mm$^2$/m
PASS - Area of reinforcement provided is greater than area of reinforcement required

Deflection control - Section 7.4
Limiting span to depth ratio; 40 Actual span to depth ratio; 13.7
PASS - Span to depth ratio is less than deflection control limit

Crack control - Section 7.3
Limiting crack width; w_{c,max} = 0.3 mm; Maximum crack width; w_a = 0.16 mm
PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2
Design shear force; V = 13.6 kN/m; Design shear resistance; V_{Rd.c} = 108.6 kN/m
PASS - Design shear resistance exceeds design shear force

Horizontal reinforcement parallel to face of stem - Section 9.6
Min.area of reinforcement; A_{b.min} = 250 mm$^2$/m; Max.spacing of reinforcement; S_{max,prov} = 400 mm
Trans.reinforcement provided; 10 dia.bars @ 200 c/c; Trans.reinforcement provided; A_{b,prov} = 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 = 450 mm
Rectangular section in flexure - Section 6.1
Design bending moment; M = 174.3 kNm/m; K = 0.036; K' = 0.207
Tens.reinforcement required; A_{sr,req} = 250 mm$^2$/m
Tens.reinforcement provided; 12 dia.bars @ 200 c/c; Tens.reinforcement provided; A_{sr,prov} = 1579 mm$^2$/m
Min.area of reinforcement; A_{sr,min} = 250 mm$^2$/m; Max.area of reinforcement; A_{sr,max} = 10000 mm$^2$/m
PASS - Area of reinforcement provided is greater than area of reinforcement required

Crack control - Section 7.3
Limiting crack width; w_{c,max} = 0.3 mm; Maximum crack width; w_a = 0.298 mm
PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2
Design shear force; V = 44.8 kN/m; Design shear resistance; V_{Rd.c} = 108.6 kN/m
PASS - Design shear resistance exceeds design shear force

Check stem design at prop
Depth of section; h = 250 mm
Reinforcement details

- 10 dia bars @ 200 c/c horizontal reinforcement parallel to face of stem
- 12 dia bars @ 200 c/c
- 12 dia bars @ 200 c/c
- 10 dia bars @ 200 c/c
- 16 dia bars @ 200 c/c
- 20 dia bars @ 199 c/c transverse reinforcement in base
- 12 dia bars @ 200 c/c
- 30
- 50

150
## Retaining wall analysis - FRONT RETAINING WALL AS CANTIELVER

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**: $h_{\text{stem}} = 2800$ mm
- **Stem thickness**: $t_{\text{stem}} = 250$ mm
- **Angle to rear face of stem**: $\alpha = 90$ deg
- **Toe length**: $l_{\text{toe}} = 2000$ mm
- **Base thickness**: $t_{\text{base}} = 450$ mm
- **Base density**: $\gamma_{\text{base}} = 25$ kN/m$^3$
- **Height of retained soil**: $h_{\text{ret}} = 2600$ mm
- **Angle of soil surface**: $\beta = 0$ deg
- **Depth of cover**: $d_{\text{cover}} = 0$ mm
- **Height of water**: $h_{\text{water}} = 1600$ mm
- **Water density**: $\gamma_{w} = 9.8$ kN/m$^3$

#### Retained soil properties
- **Soil type**: Medium dense well graded sand and gravel
- **Moist density**: $\gamma_{m} = 21$ kN/m$^3$
- **Saturated density**: $\gamma_{s} = 22.3$ kN/m$^3$
- **Characteristic effective shear resistance angle**: $\varphi'_{s} = 35$ deg
- **Characteristic wall friction angle**: $\delta_{s} = 17.5$ deg

#### Base soil properties
- **Soil type**: Medium dense well graded sand and gravel
- **Soil density**: $\gamma_{b} = 20$ kN/m$^3$
- **Characteristic effective shear resistance angle**: $\varphi'_{b} = 30$ deg
- **Characteristic wall friction angle**: $\delta_{b} = 15$ deg
- **Characteristic base friction angle**: $\delta_{bb} = 20$ deg

#### Presumed bearing capacity: $P_{\text{bearing}} = 125$ kN/m$^2$

### Loading details
- **Permanent surcharge load**: $G = 5$ kN/m$^2$
- **Variable surcharge load**: $Q = 20$ kN/m$^2$

### Calculate retaining wall geometry
- **Base length**: $l_{\text{base}} = 3250$ mm
- **Saturated soil height**: $h_{\text{sat}} = 1600$ mm
- **Moist soil height**: $h_{\text{moist}} = 1000$ mm
- **Length of surcharge load**: $l_{\text{sur}} = 0$ mm
- **Vertical distance**: $x_{\text{sur},v} = 3250$ mm
- **Horizontal distance**: $x_{\text{sur},h} = 1525$ mm
- **Effective height of wall**: $h_{\text{eff}} = 3050$ mm
- **Area of wall stem**: $A_{\text{stem}} = 0.7$ m$^2$
- **Area of wall base**: $A_{\text{base}} = 1.463$ m$^2$
- **Vertical distance**: $x_{\text{base}} = 3125$ mm
- **Area of base**: $A_{\text{base}} = 1.625$ m$^2$

#### Using Coulomb theory
- **Active pressure coefficient**: $K_A = 0.246$
- **Passive pressure coefficient**: $K_P = 4.977$

### Bearing pressure check
- **Total**:
  - $F_{\text{total}} = F_{\text{base}} + F_{\text{sat}} + F_{\text{moist}} + F_{\text{water}} + F_{\text{sur}} = 54.1$ kN/m

#### Vertical forces on wall
- **Total**:
  - $F_{\text{total}} = F_{\text{base}} + F_{\text{sat}} + F_{\text{moist}} + F_{\text{water}} + F_{\text{sur}} = 47.5$ kN/m

#### Horizontal forces on wall
- **Total**:
  - $M_{\text{total}} = M_{\text{base}} + M_{\text{sat}} + M_{\text{moist}} + M_{\text{water}} + M_{\text{sur}} = 52.3$ kN/m

#### Moments on wall
- **Total**:
  - $M_{\text{total}} = M_{\text{base}} + M_{\text{sat}} + M_{\text{moist}} + M_{\text{water}} + M_{\text{sur}} = 52.3$ kN/m
Check bearing pressure
Propping force; \( P_{\text{prop, base}} = 47.5 \text{ kN/m} \)
Bearing pressure at toe; \( q_{\text{toe}} = 37.3 \text{ kN/m}^2 \)
Bearing pressure at heel; \( q_{\text{heel}} = 0 \text{ kN/m}^2 \)
Factor of safety; \( F_{\text{so}} = 3.355 \)
\textbf{PASS - Allowable bearing pressure exceeds maximum applied bearing pressure}

RETTAINING WALL DESIGN

Concrete details - Table 3.1 - Strength and deformation characteristics for concrete
Concrete strength class; C32/40
Char comp.cylinder strength; \( f_{ck} = 32 \text{ N/mm}^2 \)
Secant modulus of elasticity; \( E_{sk} = 33346 \text{ N/mm}^2 \)
Design comp.concrete strength; \( f_{\text{cd}} = 18.1 \text{ N/mm}^2 \)
Reinforcement details
Characteristic yield strength; \( f_{yk} = 500 \text{ N/mm}^2 \)
Design yield strength; \( f_{yd} = 435 \text{ N/mm}^2 \)
Cover to reinforcement
Front face of stem; \( c_v = 30 \text{ mm} \)
Top face of base; \( c_v = 30 \text{ mm} \)

\textbf{PASS - Area of reinforcement provided is greater than area of reinforcement required}

Check base design at toe
Depth of section; \( h = 450 \text{ mm} \)
Rectangular section in flexure - Section 6.1
Design bending moment; \( M = 83.3 \text{ kNm/m} \)
Design shear force; \( V = 37 \text{ kN/m} \)
Crack control - Section 7.3
Limiting crack width; \( w_{\text{cr}} = 0.3 \text{ mm} \)

\textbf{PASS - Area of reinforcement provided is greater than area of reinforcement required}

Check stem design at base of stem
Depth of section; \( h = 250 \text{ mm} \)
Rectangular section in flexure - Section 6.1
Design bending moment; \( M = 55.8 \text{ kNm/m} \)
Tens.reinforcement required; \( A_{\text{b,req}} = 704 \text{ mm}^2/\text{m} \)
Min.area of reinforcement; \( A_{\text{b,min}} = 302 \text{ mm}^2/\text{m} \)
Max.area of reinforcement; \( A_{\text{b,max}} = 10000 \text{ mm}^2/\text{m} \)
\textbf{PASS - Area of reinforcement provided is greater than area of reinforcement required}

Deflection control - Section 7.4
Limiting span to depth ratio; \( \lambda = 16 \)
Actual span to depth ratio; \( \lambda = 14.6 \)
\textbf{PASS - Span to depth ratio is less than deflection control limit}

Check stem design at base of stem
Depth of section; \( h = 450 \text{ mm} \)
Rectangular section in flexure - Section 6.1
Design bending moment; \( M = 83.3 \text{ kNm/m} \)

\textbf{PASS - Area of reinforcement provided is greater than area of reinforcement required}

Deflection control - Section 7.4
Limiting span to depth ratio; \( \lambda = 16 \)
Actual span to depth ratio; \( \lambda = 14.6 \)
\textbf{PASS - Span to depth ratio is less than deflection control limit}

Crack control - Section 7.3
Limiting crack width; \( w_{\text{cr}} = 0.3 \text{ mm} \)
Max.crack width; \( w_{\text{max}} = 0.139 \text{ mm} \)
\textbf{PASS - Maximum crack width is less than limiting crack width}

Check base design at toe
Depth of section; \( h = 450 \text{ mm} \)
Rectangular section in flexure - Section 6.1
Design bending moment; \( M = 83.3 \text{ kNm/m} \)
Tens.reinforcement required; \( A_{\text{b,req}} = 517 \text{ mm}^2/\text{m} \)
Min.area of reinforcement; \( A_{\text{b,min}} = 251 \text{ mm}^2/\text{m} \)
Max.area of reinforcement; \( A_{\text{b,max}} = 393 \text{ mm}^2/\text{m} \)
\textbf{PASS - Area of reinforcement provided is greater than area of reinforcement required}

Crack control - Section 7.3
Limiting crack width; \( w_{\text{cr}} = 0.3 \text{ mm} \)
Max.crack width; \( w_{\text{max}} = 0.139 \text{ mm} \)
\textbf{PASS - Maximum crack width is less than limiting crack width}

Check base design at toe
Depth of section; \( h = 450 \text{ mm} \)
Rectangular section in flexure - Section 6.1
Design bending moment; \( M = 83.3 \text{ kNm/m} \)
Tens.reinforcement required; \( A_{\text{b,req}} = 517 \text{ mm}^2/\text{m} \)
Min.area of reinforcement; \( A_{\text{b,min}} = 251 \text{ mm}^2/\text{m} \)
Max.area of reinforcement; \( A_{\text{b,max}} = 393 \text{ mm}^2/\text{m} \)
\textbf{PASS - Area of reinforcement provided is greater than area of reinforcement required}

Deflection control - Section 7.4
Limiting span to depth ratio; \( \lambda = 16 \)
Actual span to depth ratio; \( \lambda = 14.6 \)
\textbf{PASS - Span to depth ratio is less than deflection control limit}

Crack control - Section 7.3
Limiting crack width; \( w_{\text{cr}} = 0.3 \text{ mm} \)
Max.crack width; \( w_{\text{max}} = 0.139 \text{ mm} \)
\textbf{PASS - Maximum crack width is less than limiting crack width}

Check base design at toe
Depth of section; \( h = 450 \text{ mm} \)
Rectangular section in flexure - Section 6.1
Design bending moment; \( M = 83.3 \text{ kNm/m} \)
Tens.reinforcement required; \( A_{\text{b,req}} = 517 \text{ mm}^2/\text{m} \)
Min.area of reinforcement; \( A_{\text{b,min}} = 251 \text{ mm}^2/\text{m} \)
Max.area of reinforcement; \( A_{\text{b,max}} = 393 \text{ mm}^2/\text{m} \)
\textbf{PASS - Area of reinforcement provided is greater than area of reinforcement required}

Crack control - Section 7.3
Limiting crack width; \( w_{\text{cr}} = 0.3 \text{ mm} \)
Max.crack width; \( w_{\text{max}} = 0.139 \text{ mm} \)
\textbf{PASS - Maximum crack width is less than limiting crack width}

Check base design at toe
Depth of section; \( h = 450 \text{ mm} \)
Rectangular section in flexure - Section 6.1
Design bending moment; \( M = 83.3 \text{ kNm/m} \)
Tens.reinforcement required; \( A_{\text{b,req}} = 517 \text{ mm}^2/\text{m} \)
Min.area of reinforcement; \( A_{\text{b,min}} = 251 \text{ mm}^2/\text{m} \)
Max.area of reinforcement; \( A_{\text{b,max}} = 393 \text{ mm}^2/\text{m} \)
\textbf{PASS - Area of reinforcement provided is greater than area of reinforcement required}

Crack control - Section 7.3
Limiting crack width; \( w_{\text{cr}} = 0.3 \text{ mm} \)
Max.crack width; \( w_{\text{max}} = 0.139 \text{ mm} \)
\textbf{PASS - Maximum crack width is less than limiting crack width}
Reinforcement details

- 10 dia bars @ 200 c/c horizontal reinforcement parallel to face of stem
- 16 dia bars @ 200 c/c
- 20 dia bars @ 199 c/c transverse reinforcement in base
APPENDIX D - STRUCTURAL CALCULATIONS, TEMPORARY WORKS

Note: Calculations produced are for planning purposes only. NOT FOR CONSTRUCTION
Analysis - FRONT RETAINING WALL IN TEMP CONDITION

Geometry

Geometry (m) - Steel (EC3) - UKC 152x152x30

Span Length (m) Section Start Support End Support
1 0.1 UKC 152x152x30 Free Pinned
2 2.3 UKC 152x152x30 Pinned Roller Pin Z
3 0.1 UKC 152x152x30 Roller Pin Z Free

UKC 152x152x30: $A = 38 \text{ cm}^2$, $I_y = 1748 \text{ cm}^4$, $I_z = 560 \text{ cm}^4$, $A_y = 26 \text{ cm}^2$, $A_z = 10 \text{ cm}^2$

Steel (EC3): Density 7850 kg/m$^3$, Youngs 210 kN/mm$^2$, Shear 80.8 kN/mm$^2$, Thermal 0.000012 °C$^{-1}$

Member Loads

<table>
<thead>
<tr>
<th>Member</th>
<th>Load case</th>
<th>Load Type</th>
<th>Orientation</th>
<th>Description</th>
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<tbody>
<tr>
<td>Wall</td>
<td>Permanent</td>
<td>UDL</td>
<td>GlobalX</td>
<td>2.25 kN/m</td>
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<td>UDL</td>
<td>GlobalX</td>
<td>9 kN/m</td>
</tr>
<tr>
<td>Wall</td>
<td>Soil</td>
<td>VDL</td>
<td>GlobalX</td>
<td>11.25 kN/m to 0 kN/m</td>
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Load combination factors

<table>
<thead>
<tr>
<th>Load combination</th>
<th>Self Weight</th>
<th>Permanent</th>
<th>Imposed</th>
<th>Soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>G + Q + S (Service)</td>
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<td>1.00</td>
<td>1.00</td>
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<tr>
<td>1.25G + 1.5Q + 1.25S (Strength)</td>
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Reactions

Load case: Self Weight

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<tr>
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<th>Moment</th>
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<tbody>
<tr>
<td></td>
<td>Fx (kN)</td>
<td>Fz (kN)</td>
</tr>
<tr>
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<td>0.7</td>
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<tr>
<td>3</td>
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<td>0</td>
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</tbody>
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Load case: Permanent

<table>
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<tr>
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<th>Force</th>
<th>Moment</th>
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<td>Fz (kN)</td>
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Load case: Imposed

<table>
<thead>
<tr>
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<th>Force</th>
<th>Moment</th>
</tr>
</thead>
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<td>Fz (kN)</td>
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Load case: Soil

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
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<td>Fz (kN)</td>
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Load combination: G + Q + S (Service)

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<tr>
<th>Node</th>
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<th>Moment</th>
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</table>

Load combination: 1.25G + 1.5Q + 1.25S (Strength)

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<th>Force</th>
<th>Moment</th>
</tr>
</thead>
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### Element end forces

#### Load case: Self Weight

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<th>Length (m)</th>
<th>Nodes Start/End</th>
<th>Axial force (kN)</th>
<th>Shear force (kN)</th>
<th>Moment (kNm)</th>
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<td>2.3</td>
<td>2 -0.7</td>
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#### Load case: Permanent

<table>
<thead>
<tr>
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<th>Moment (kNm)</th>
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<td>2.3</td>
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#### Load case: Imposed

<table>
<thead>
<tr>
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<th>Moment (kNm)</th>
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<td>0 0</td>
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</tr>
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<td>0.1</td>
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<td>-0.9 0</td>
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<td>0</td>
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<td>0 0</td>
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#### Load case: Soil

<table>
<thead>
<tr>
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<th>Length (m)</th>
<th>Nodes Start/End</th>
<th>Axial force (kN)</th>
<th>Shear force (kN)</th>
<th>Moment (kNm)</th>
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<td>0 0</td>
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</tr>
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<td>2.3</td>
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<td>-1.1 -0.1</td>
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<td>-0.9 0</td>
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<td></td>
<td></td>
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#### Load combination: G + Q + S (Service)

<table>
<thead>
<tr>
<th>Element</th>
<th>Length (m)</th>
<th>Nodes Start/End</th>
<th>Axial force (kN)</th>
<th>Shear force (kN)</th>
<th>Moment (kNm)</th>
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<tbody>
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<td>0 0</td>
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<tr>
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<td></td>
</tr>
<tr>
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<td>0.1</td>
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<td>-1.7 -0.1</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>4 0</td>
<td>0 0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Load combination: 1.25G + 1.5Q + 1.25S (Strength)

<table>
<thead>
<tr>
<th>Element</th>
<th>Length (m)</th>
<th>Nodes Start/End</th>
<th>Axial force (kN)</th>
<th>Shear force (kN)</th>
<th>Moment (kNm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>0 0</td>
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<tr>
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<td></td>
<td>2 0</td>
<td>0 -3</td>
<td>-0.2</td>
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</table>

### Forces

#### Member results

**Envelope - All load cases**

<table>
<thead>
<tr>
<th>Member</th>
<th>Position (m)</th>
<th>Shear force (kN)</th>
<th>Moment (kNm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall</td>
<td>0.1</td>
<td>10.4 (max abs)</td>
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<tr>
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<td>1.25</td>
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<tr>
<td></td>
<td></td>
<td>5.9 (max)</td>
<td>0</td>
</tr>
<tr>
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<td>2.4</td>
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</tr>
<tr>
<td></td>
<td>2.5</td>
<td>0.9 (max)</td>
<td>0</td>
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</table>

**Envelope - Service combinations**

<table>
<thead>
<tr>
<th>Member</th>
<th>Position (m)</th>
<th>Deflection (mm)</th>
</tr>
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<tbody>
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<td>-0.2 (min)</td>
</tr>
<tr>
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<td>1.235</td>
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**Envelope - Strength combinations**

<table>
<thead>
<tr>
<th>Member</th>
<th>Position (m)</th>
<th>Shear force (kN)</th>
<th>Moment (kNm)</th>
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</thead>
<tbody>
<tr>
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<td>15.4 (max)</td>
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**Load case: Permanent**

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<tr>
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<th>Length (m)</th>
<th>Nodes Start/End</th>
<th>Axial force (kN)</th>
<th>Shear force (kN)</th>
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<tr>
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<tr>
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<td></td>
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<td>0 0</td>
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**Load case: Imposed**

<table>
<thead>
<tr>
<th>Element</th>
<th>Length (m)</th>
<th>Nodes Start/End</th>
<th>Axial force (kN)</th>
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**Load case: Soil**

<table>
<thead>
<tr>
<th>Element</th>
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<th>Nodes Start/End</th>
<th>Axial force (kN)</th>
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<th>Moment (kNm)</th>
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</table>
Steel beam analysis & design (EN1993-1-1:2005) - WALER BEAMS

In accordance with EN1993-1-1:2005 incorporating Corrigenda February 2006 and April 2009 and the UK national annex.

Analysis results

Maximum moment:
- Maximum moment span 1; \( M_{s1_{max}} = 9.4 \text{kNm} \)
- Maximum moment span 1 segment 1; \( M_{s1_{seg1_{max}}} = 9.4 \text{kNm} \)
- Maximum moment span 1 segment 3; \( M_{s1_{seg3_{max}}} = 9.4 \text{kNm} \)
- Maximum moment span 4; \( M_{s4_{max}} = 9.4 \text{kNm} \)
- Maximum moment span 5; \( M_{s5_{max}} = 9.4 \text{kNm} \)

Maximum shear:
- Maximum shear; \( V_{s1_{max}} = 33.3 \text{kN} \)
- Maximum shear span 1; \( V_{s1_{max}} = 33.3 \text{kN} \)
- Maximum shear span 1 segment 1; \( V_{s1_{seg1_{max}}} = 33.3 \text{kN} \)
- Maximum shear span 1 segment 2; \( V_{s1_{seg2_{max}}} = 33.3 \text{kN} \)
- Maximum shear span 1 segment 3; \( V_{s1_{seg3_{max}}} = 33.3 \text{kN} \)
- Maximum shear span 2; \( V_{s2_{max}} = 33.3 \text{kN} \)
- Maximum shear span 3; \( V_{s3_{max}} = 33.3 \text{kN} \)
- Maximum shear span 4; \( V_{s4_{max}} = 33.3 \text{kN} \)
- Maximum shear span 5; \( V_{s5_{max}} = 33.3 \text{kN} \)

Deflection;
- Deflection; \( \delta_{s1_{max}} = 1.9 \text{mm} \)
- Deflection span 1; \( \delta_{s1_{seg1_{max}}} = 1.9 \text{mm} \)
- Deflection span 2; \( \delta_{s1_{seg2_{max}}} = 1.9 \text{mm} \)
- Deflection span 3; \( \delta_{s1_{seg3_{max}}} = 1.9 \text{mm} \)
- Deflection span 4; \( \delta_{s1_{seg4_{max}}} = 1.9 \text{mm} \)
- Deflection span 5; \( \delta_{s1_{seg5_{max}}} = 1.9 \text{mm} \)

Maximum reaction at support A; \( R_{A_{max}} = 0 \text{kN} \)

Maximum reaction at support B; \( R_{B_{max}} = 33.3 \text{kN} \)

Maximum reaction at support C; \( R_{C_{max}} = 33.3 \text{kN} \)

Maximum reaction at support D; \( R_{D_{max}} = 33.3 \text{kN} \)

Maximum reaction at support E; \( R_{E_{max}} = 33.3 \text{kN} \)

Maximum reaction at support F; \( R_{F_{max}} = 33.3 \text{kN} \)

Support conditions

Support A: Vertically free
Support B: Vertically restrained
Support C: Vertically restrained
Support D: Vertically restrained
Support E: Vertically restrained
Support F: Vertically free

Applied loading

Beam loads:
- Permanent self weight of beam \( x \times 1 \text{ kN/m} \)
- Permanent full UDL \( 12.4 \text{ kN/m} \)
- Variable full UDL \( 11.6 \text{ kN/m} \)

Load combinations

Load combination 1:
- Support A: Permanent \( x \times 1.25 \text{kN/m} \)
- Variable \( x \times 1.50 \text{kN/m} \)

Support B: Permanent \( x \times 1.25 \text{kN/m} \)
Support C: Permanent \( x \times 1.25 \text{kN/m} \)
Support D: Permanent \( x \times 1.25 \text{kN/m} \)
Support E: Permanent \( x \times 1.25 \text{kN/m} \)
Support F: Permanent \( x \times 1.25 \text{kN/m} \)
Steel member design (EN1993-1-1:2005) - PROPS

In accordance with EN1993-1-1:2005 incorporating Corrigenda February 2006 and April 2009 and the UK national annex

Partial factors - Section 6.1:
\( \gamma_M = 1; \quad \gamma_N = 1; \quad \gamma_s = 1.1 \)

Design section 1

Section details:
UKC 152x152x30 (Tata Steel Advance)
Steel grade: S275
Nominal yield strength: \( f_y = 275 \text{ N/mm}^2 \)
Nominal ult. tensile strength: \( f_u = 410 \text{ N/mm}^2 \)

Analysis results
Design bending moment - Major axis; \( M_{b,y,Ed} = 5 \text{ kNm} \)
Design bending moment - Minor axis; \( M_{b,z,Ed} = 5 \text{ kNm} \)
Design shear force - Major axis; \( V_{b,y,Ed} = 75 \text{ kN} \)
Design shear force - Minor axis; \( V_{b,z,Ed} = 75 \text{ kN} \)
Design axial compression force; \( N_{Ed} = 75 \text{ kN} \)

Restraint spacing
Major axis lateral restraint; \( L_y = 5000 \text{ mm} \)
Minor axis lateral restraint; \( L_z = 5000 \text{ mm} \)
Torsional restraint; \( L_T = 5000 \text{ mm} \)

Classification of cross sections - Section 5.5
Internal compression parts; Class 1
Outstand flanges; Class 1

Check compression - Section 6.2.4
Design compression force; \( N_{Ed} = 75 \text{ kN} \)
Design resistance of section; \( N_{Rc} = 1052.2 \text{ kN} \)

Check y-y axis flexural buckling resistance - Section 6.3.1.1
Design buckling resistance; \( N_{b,y,Rd} = 727.9 \text{ kN} \)

Check z-z axis flexural buckling resistance - Section 6.3.1.1
Design buckling resistance; \( N_{b,z,Rd} = 329.3 \text{ kN} \)

Check torsional and torsional-flexural buckling resistance - Section 6.3.1.1
Design buckling resistance; \( N_{b,T,Rd} = 662.4 \text{ kN} \)

Section is class 1
Check shear - Section 6.2.6
Design shear force; \( V_{y,Ed} = 75 \text{ kN} \); Design shear resistance; \( V_{c,y,Rd} = 183.5 \text{ kN} \)
\[ \frac{V_{y,Ed}}{V_{c,y,Rd}} = 0.409 \]  
**PASS - Design shear resistance exceeds design shear force**

Design shear force; \( V_{z,Ed} = 75 \text{ kN} \); Design shear resistance; \( V_{c,z,Rd} = 424 \text{ kN} \)
\[ \frac{V_{z,Ed}}{V_{c,z,Rd}} = 0.177 \]  
**PASS - Design shear resistance exceeds design shear force**

Check bending moment - Section 6.2.5
Design bending moment; \( M_{y,Ed} = 5 \text{ kNm} \); Bending resistance moment; \( M_{c,y,Rd} = 68.1 \text{ kNm} \)
\[ \frac{M_{y,Ed}}{M_{c,y,Rd}} = 0.073 \]  
**PASS - Design bending resistance moment exceeds design bending moment**

Check buckling resistance - Section 6.3.2.1
Buckling resistance moment; \( M_{b,y,Rd} = 48.7 \text{ kNm} \); \( M_{y,Ed} = 68.1 \text{ kNm} \)
\[ \frac{M_{y,Ed}}{M_{b,y,Rd}} = 0.103 \]  
**PASS - Design buckling resistance moment exceeds design bending moment**

Check bending moment - Section 6.2.5
Design bending moment; \( M_{z,Ed} = 5 \text{ kNm} \); Bending resistance moment; \( M_{c,z,Rd} = 30.7 \text{ kNm} \)
\[ \frac{M_{z,Ed}}{M_{c,z,Rd}} = 0.163 \]  
**PASS - Design bending resistance moment exceeds design bending moment**

Check bending and axial force - Section 6.2.9
Bending and axial force check; \( N_{y,lim} = 124.1 \text{ kN} \); \( N_{Ed} = 68.1 \text{ kN} \)
\[ N_{Ed} / N_{y,lim} = 0.542 \]  
**Allowance need not be made for the effect of the axial force on the plastic resistance moment about the y-y axis**

Bending and axial force check; \( N_{z,lim} = 248.1 \text{ kN} \); \( N_{Ed} = 68.1 \text{ kN} \)
\[ N_{Ed} / N_{z,lim} = 0.276 \]  
**Allowance need not be made for the effect of the axial force on the plastic resistance moment about the z-z axis**

For bi-axial bending; \[ \frac{M_{y,Ed}}{M_{pl,y,Rd}} + \frac{M_{z,Ed}}{M_{pl,z,Rd}} \]  
\[ = 0.168 \]  
**PASS - Biaxial bending utilisation is acceptable**

Interaction factors \( k_i \) for members susceptible to torsional deformations - Table B.2
Interaction formulae; \( \max(0.342, 0.542) = 0.542 \)  
**PASS - Combined bending and compression checks are satisfied**