STRUCTURAL CALCULATION NOTES

PROJECT: PROPOSED WAREHOUSE

LOCATION: RUBAVU

CLIENT: ALPHA LOGISTICS RWANDA

JULY, 2016
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INTRODUCTION
This report is about the structure calculation notes of warehouse 1.

1. DESIGN CODES AND TOOLS

1.1. GENERAL
Design life: 100 years
Function: warehouse

1.2. STANDARDS
LOADING
- CP3 Chapter V-2:1972 Code of basic data for the design of buildings, Part 2: - Wind loads

Concrete design:
BS8110, Part-1:2002 Structural use of concrete

NF EN 1992-1-1/NA: 2007 Reinforced concrete wall design

MATERIALS
Concrete: Concrete grade: C25/30

1.3. SOFTWARE
Autodesk Revit Structure 2016: Structure definition and detailing
Autodesk Robot Structural Analysis Professional 2016: Load definition, Analysis and RC members design
CSC Tedds: Individual member analysis and desigining or design
2. STRUCTURE DEFINITION AND LOADING

2.1. STRUCTURE DEFINITION

The structure was defined in Revit; as we define the physical element in Revit, the analytical model was immediately produced to be sent to the structure analysis program.

Below are 3D Views of the Architectural and structural model and Ground floor of the building. The structure frame arrangement and detailed drawings will be provided in the annex of this report.

![Structural Framing of the Building](image)

Picture 1: Structural Framing of the Building

2.2. MEMBER SIZING AND ARRANGEMENT

Before analyzing the structure, we defined it. By defining the structure, we arranged the structural members carefully to avoid alteration of the beautiful Architecture of building; we also avoided to interfere with MEP installations.

We used shear walls in the building around stair’ cases and elevators; these shear walls are effective for seismic forces.
2.3. LOAD DEFINITION
After defining the structure in Revit, we transferred the analytical model of the structure to Robot for Load Definition, Structure Analysis and structural member design and resizing where the initial size was not suitable.

DEAD LOAD
Self-weight of the structural members will be calculated by computer program automatically.

Unit weight of concrete block masonry: 18.5kN/m³

Concrete unit weight: 25kN/ m³
Roof iron sheets: 0.5kN/m²

LIVE LOAD
Accessible roof for Repair: 1kN/m²

SEISMIC LOAD DEFINITION
Code parameters

To complete the seismic analysis according to the rules given in this code, we defined the following parameters in Robot:

- **Site class** (A, B, C, D, E or F) based on the site soil properties, classified according to the table 1613.5.2 (Site Class Classification)
  - Site Class: D
- **Spectral response accelerations**, as specified in Section 1613.5.1, mapped in Figures 1613.5(1) through 1613.5(14)
  - $S_1$ - spectral acceleration for 1-second period
  - $S_s$ - spectral acceleration for short periods

For Rubavu: $S_1=1.24$ and $S_s=0.56$

- $T_1$ - long-period transition period, specified according to the ASCE 7-05 code, as shown in the Figures 22-15 through 22-20
- $I$ - importance factor, as specified in ASCE 7-05, Section 11.5.1.
  - Buildings and other structures that represent asubstantial hazard to human life or represent significant economic loss in the event of failure. $I=1.25$
- $R$ - response modification coefficient, as specified in ASCE 7-05, Tables 12.2-1
Reinforced Concrete structure with shear walls

Base shear

Base shear force is calculated according to the formula: 

\[ F_x = V \cdot w_x \cdot h_x / (\Sigma w_i \cdot h_i) \] (eq. 12.8-11 and 12.8-12) where:

- \( w_x \) and \( w_i \) - floor weight
- \( h_x \) - height from base level to appropriate floor level
- \( V \) - base shear force (this value is already calculated in Robot)
- \( k \) - exponent depending on the period value

**WIND LOAD**

Dynamic pressure, \( q \) = 0.613 \( V \)

\[ q = 0.613 \times 33.86^2 \]

\[ = 702.80 \text{ N/m}^2 \]

\[ = 0.703 \text{ kN/m}^2 \]

Design wind speed, \( V_s = V \times S_1 \times S_2 \times S_3 \) (Refer 5.1, CP 3: Chapter V-2:1972)

\[ = 30 \times 1.36 \times 0.83 \times 1 \]

\[ = 33.86 \text{ m/s} \]

Basic wind speed, \( V = 30 \text{ m/s} \)

Topography factor, \( S_1 = 1.36 \) (Conservative for Hilly terrain)

Ground roughness, \( S_2 = 0.79 + (0.93 - 0.79) \times (6.5 - 5) / (10 - 5) \)

\[ = 0.83 \] (Ground roughness – 2, Class – A)

Statistical factor, \( S_3 = 1 \) (Conservative, Fig 2, CP3: Chapter V-2:1972)
Wind pressure

| For beams and | = 1.9 | (Refer Table 17, CP 3: Chapter V-2:1972) |
| For pipes     | = 1.2 |

2.4. LOAD COMBINATION

Loads have been combined according to BS-EN 1990:2002 NA: 2004.

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<th>Subnature</th>
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<th>$\gamma_{\text{min}}$</th>
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3. STRUCTURE ANALYSIS

After loading the structure, we used the software (Robot) to analyze and to display the analysis results. The image captions below shows the display of some results after analyzing the structure.

Fig2: Structure deformation due to ULS Load combinations.

3.1. STRUCTURE ANALYSIS RESULTS

After the structural analysis, we extracted results in form of values, graphs, diagrams and other. And we used those values to design our members. Here are some graphics of some values.
Image: Reactions due to ULS load combination
4. STRUCTURAL MEMBER DESIGN

After determining the loads in each structural member, we designed those reinforced concrete members and steel trusses to safely withstand loads imposed upon them. We sized the members to optimize the cost vs. the strength.

Below, there are detailed calculation notes of reinforced concrete members and steel truss members.
STEEL TRUSS DESIGN

Bottom Chords

ANALYSIS TYPE: Code Group Verification

CODE GROUP: 1 BottomChords
MEMBER: 19 POINT: 1 COORDINATE: x = 0.00 L = 0.00 m

LOADS:
Governing Load Case: 3 ULS /1/ 1*1.35 + 2*1.50

MATERIAL:
Steel (S235) fy = 235.00 MPa

SECTION PARAMETERS: SHSC 70x70x3.6
h=7.0 cm gM0=1.00 gM1=1.00
b=7.0 cm Ay=4.62 cm2
tw=0.4 cm Iy=66.50 cm4
tf=0.4 cm Wply=22.70 cm3

INTERNAL FORCES AND CAPACITIES:
N,Ed = 186.55 kN
Nc,Rd = 216.91 kN
Nb,Rd = 197.10 kN
Class of section = 1

LATERAL BUCKLING PARAMETERS:

BUCKLING PARAMETERS:
About y axis:
Ly = 1.38 m Lam_y = 0.55
Lcr,y = 1.38 m Xy = 0.91
Lamy = 51.45

About z axis:
Lz = 1.38 m Lam_z = 0.55
Lcr,z = 1.38 m Xz = 0.91
Lamz = 51.45

VERIFICATION FORMULAS:
Section strength check:
N,Ed/Nc,Rd = 0.86 < 1.00 (6.2.4.(1))

Global stability check of member:
Lambda,y = 51.45 < Lambda,max = 210.00
Lambda,z = 51.45 < Lambda,max = 210.00 STABLE

N,Ed/Nb,Rd = 0.95 < 1.00 (6.3.1.1.(1))

Section OK !!

Top Chords

ANALYSIS TYPE: Code Group Verification
CODE GROUP: 2 TopChords
MEMBER: 55 POINT: 1 COORDINATE: x = 0.00 L = 0.00 m

LOADS:
Governing Load Case: 3 ULS /1/ 1*1.35 + 2*1.50

MATERIAL:
Steel (S235) fy = 235.00 MPa

SECTION PARAMETERS: SHSC 70x70x3.6
h=7.0 cm gM0=1.00 gM1=1.00
b=7.0 cm Ay=4.62 cm2 Az=4.62 cm2 Ax=9.23 cm2
tw=0.4 cm ly=66.50 cm4 Iz=66.50 cm4 lx=108.00 cm4
tf=0.4 cm Wply=22.70 cm3 Wplz=22.70 cm3

INTERNAL FORCES AND CAPACITIES:
N,Ed = 167.62 kN
Nc,Rd = 216.91 kN
Nb,Rd = 197.10 kN

LATERAL BUCKLING PARAMETERS:
Ly = 1.38 m Lam_y = 0.55
Lcr,y = 1.38 m Xy = 0.91
Lamy = 51.45

VERIFICATION FORMULAS:
Section strength check:
N,Ed/Nc,Rd = 0.77 < 1.00 (6.2.4.(1))

Global stability check of member:
Lambda,y = 51.45 < Lambda,max = 210.00
Lambda,z = 51.45 < Lambda,max = 210.00 STABLE

Section OK !!!

Diagonals

ANALYSIS TYPE: Code Group Verification

CODE GROUP: 3 Diagonals
MEMBER: 76 POINT: 1 COORDINATE: x = 0.00 L = 0.00 m

LOADS:
Governing Load Case: 3 ULS /1/ 1*1.35 + 2*1.50
MATERIAL:
Steel (S235)  fy = 235.00 MPa

SECTION PARAMETERS: SHSC 60x60x3
h=6.0 cm  gM0=1.00  gM1=1.00
b=6.0 cm  Ay=3.31 cm2  Az=3.31 cm2  Ax=6.61 cm2
tw=0.3 cm  Iy=35.10 cm4  Iz=35.10 cm4  Ix=57.10 cm4
tf=0.3 cm  Wply=14.00 cm3  Wplz=14.00 cm3

INTERNAL FORCES AND CAPACITIES:
N,Ed = 94.99 kN
Nc,Rd = 155.34 kN
Nb,Rd = 97.15 kN

INTERNAL FORCES AND CAPACITIES:
N,Ed = 94.99 kN
Nc,Rd = 155.34 kN
Nb,Rd = 97.15 kN

Class of section = 1

BUCKLING PARAMETERS:

About y axis:
Ly = 2.29 m  Lam_y = 1.06  Xy = 0.63
Lcr,y = 2.29 m
Lamy = 99.31

About z axis:
Lz = 2.29 m  Lam_z = 1.06
Lcr,z = 2.29 m  Xz = 0.63
Lamz = 99.31

VERIFICATION FORMULAS:

Section strength check:
N,Ed/Nc,Rd = 0.61 < 1.00  (6.2.4.(1))

Global stability check of member:
Lambda,y = 99.31 < Lambda,max = 210.00
Lambda,z = 99.31 < Lambda,max = 210.00 STABLE

N,Ed/Nb,Rd = 0.98 < 1.00  (6.3.1.1.(1))

Section OK !!!

ANALYSIS TYPE: Code Group Verification

CODE GROUP: 4 Posts
MEMBER: 109  POINT: 1  COORDINATE: x = 0.00 L = 0.00 m

LOADS:
Governing Load Case: 3 ULS /1/ 1*1.35 + 2*1.50

MATERIAL:
Steel (S235)  fy = 235.00 MPa

SECTION PARAMETERS: SHSC 50x50x3
h=5.0 cm  gM0=1.00  gM1=1.00
b=5.0 cm \quad Ay=2.71 \, \text{cm}^2 \quad Az=2.71 \, \text{cm}^2 \quad Ax=5.41 \, \text{cm}^2

tw=0.3 \, \text{cm} \quad Iy=19.50 \, \text{cm}^4 \quad Iz=19.50 \, \text{cm}^4 \quad Ix=32.10 \, \text{cm}^4

tf=0.3 \, \text{cm} \quad Wply=9.39 \, \text{cm}^3 \quad Wplz=9.39 \, \text{cm}^3

-----------------------------------------------------------------------------------------------------------------------------

INTERNAL FORCES AND CAPACITIES:
N_{Ed} = 92.60 \, \text{kN}
N_{Cc,Rd} = 127.14 \, \text{kN}
N_{Nb,Rd} = 98.06 \, \text{kN}
Class of section = 1

-----------------------------------------------------------------------------------------------------------------------------

LATERAL BUCKLING PARAMETERS:

BUCKLING PARAMETERS:

About y axis:
Ly = 1.50 \, \text{m} \quad \text{Lam}_y = 0.84
Lcr_y = 1.50 \, \text{m} \quad \text{Xy} = 0.77
Lamy = 79.01

About z axis:
Lz = 1.50 \, \text{m} \quad \text{Lam}_z = 0.84
Lcr_z = 1.50 \, \text{m} \quad \text{Xz} = 0.77
Lamz = 79.01

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VERIFICATION FORMULAS:

Section strength check:
N_{Ed}/N_{Cc,Rd} = 0.73 < 1.00 \quad (6.2.4.(1))

Global stability check of member:
\text{Lambda}_{y} = 79.01 < \text{Lambda}_{max} = 210.00 \quad \text{STABLE}
\text{Lambda}_{z} = 79.01 < \text{Lambda}_{max} = 210.00 \quad \text{STABLE}

N_{Ed}/N_{Nb,Rd} = 0.94 < 1.00 \quad (6.3.1.1.(1))

-----------------------------------------------------------------------------------------------------------------------------

Section OK !!!
1 Level:

- Name: Level +5.40
- Reference level: -6.00 (m)
- Concrete creep coefficient: $\phi_p = 2.77$
- Cement class: N
- Environment class: X0
- Structure class: S1

2 Column: Column Calculation Notes

2.1 Material properties:

- Concrete: C25/30, $f_{ck} = 25.00$ (MPa)
  - Unit weight: 2501.36 (kG/m3)
  - Aggregate size: 20.0 (mm)
- Longitudinal reinforcement: $T$, $f_{yk} = 460.00$ (MPa)
- Ductility class: -
- Transversal reinforcement: $T$, $f_{yk} = 460.00$ (MPa)

2.2 Geometry:

2.2.1 Rectangular: 40.0 x 40.0 (cm)
2.2.2 Height: L: 11.40 (m)
2.2.3 Slab thickness: 0.00 (m)
2.2.4 Beam height: 0.00 (m)
2.2.5 Cover: 4.0 (cm)

2.3 Calculation options:

- Seismic dispositions: No requirements
- Precast column: no
- Pre-design: no
- Slenderness taken into account: yes
- Compression: with bending
- Ties: to slab
- Fire resistance class: No requirements

2.4 Loads:

<table>
<thead>
<tr>
<th>Case</th>
<th>Nature</th>
<th>Group</th>
<th>$\gamma_f$</th>
<th>N (kN)</th>
<th>$M_y(s)$ (kN*m)</th>
<th>$M_y(i)$ (kN*m)</th>
<th>$M_z(s)$ (kN*m)</th>
<th>$M_z(i)$ (kN*m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DL1</td>
<td>dead load(Structural)</td>
<td>123</td>
<td>1.35</td>
<td>92.21</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>LL1</td>
<td>live load(Category A)</td>
<td>123</td>
<td>1.50</td>
<td>94.48</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

$\gamma_f$ - load factor

2.5 Calculation results:

Safety factors $R_d/E_d = 2.19 > 1.0$
2.5.1 ULS/ALS Analysis

Design combination: 1.35DL1+1.50LL1 (C)  
Combination type: ULS  
Internal forces:  
\[ N_{sd} = 266.20 \text{ (kN)} \]  
\[ M_{sd} = 0.00 \text{ (kN*m)} \]  
\[ M_{sd} = 0.00 \text{ (kN*m)} \]  
Design forces:  
Cross-section in the middle of the column  
\[ N = 266.20 \text{ (kN)} \]  
\[ N^{etotz} = 12.34 \text{ (kN*m)} \]  
\[ N^{etoty} = 5.32 \text{ (kN*m)} \]  
Eccentricity:  
\[ e_{Ed} = \theta_1 \frac{L_0}{2} = 1.9 \text{ (cm)} \]  
\[ e_{Ed} = \theta_0 + \alpha h \times \alpha m = 0.00 \]  
\[ \theta_0 = 0.01 \]  
\[ \alpha h = 0.67 \]  
\[ \alpha m = (0.5(1+1/m))^{0.5} = 1.00 \]  
\[ m = 1.00 \]  
Method based on nominal stiffness  
\[ \beta = 1.23 \]  
\[ N_b = \left( \frac{\pi^2 E J}{L^2} \right)^{0.5} = 494.38 \text{ (kN)} \]  
\[ E J = K_c^*E_c^*J_c + K_s^*E_s^*J_s = 6509.89 \text{ (kN*m2)} \]  
\[ \phi_{ef} = 1.26 \]  
\[ J_c = 213333.3 \text{ (cm4)} \]  
\[ J_s = 2463.0 \text{ (cm4)} \]  
\[ K_c = 0.03 \]  
\[ K_s = 1.00 \]  
\[ M_{Ed_{min}} = 5.32 \text{ (kN*m)} \]  
\[ M_{\theta Ed} = \max \left\{ M_{\theta Ed_{min}}, \left[ \frac{1 + \frac{\beta}{(N_B / N) - 1}}{M_{\theta Ed}} \right] M_{0 \theta Ed} \right\} = 12.34 \text{ (kN*m)} \]  

2.5.1.1 Detailed analysis-Direction Y:

2.5.1.1.1 Slenderness analysis  
Non-sway structure  
<table>
<thead>
<tr>
<th>L (m)</th>
<th>L0 (m)</th>
<th>λ</th>
<th>λlim</th>
<th>Slender column</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.40</td>
<td>11.40</td>
<td>98.73</td>
<td>41.56</td>
<td></td>
</tr>
</tbody>
</table>

2.5.1.1.2 Buckling analysis  
Case: Cross-section in the middle of the column, Slenderness taken into account  
\[ M_{0 e} = 0.6^*M_{0 2} + 0.4^*M_{0 1} = 0.00 \text{ (kN*m)} \]  
\[ M_0 = \max (M_{0 e}, M_{0emin}) \]  
\[ e_a = \theta_1 \frac{L_0}{2} = 1.9 \text{ (cm)} \]  
\[ \theta_1 = \theta_0 + \alpha h \times \alpha m = 0.00 \]  
\[ \theta_0 = 0.01 \]  
\[ \alpha h = 0.67 \]  
\[ \alpha m = (0.5(1+1/m))^{0.5} = 1.00 \]  
\[ m = 1.00 \]  
Method based on nominal stiffness  
\[ \beta = 2.44 \]  
\[ M_{Ed_{min}} = 5.32 \text{ (kN*m)} \]  
\[ M_{Ed} = \max \left\{ M_{Ed_{min}}, \left[ \frac{1 + \frac{\beta}{(N_B / N) - 1}}{M_{\theta Ed}} \right] M_{0 \theta Ed} \right\} = 12.34 \text{ (kN*m)} \]  

2.5.1.2 Detailed analysis-Direction Z:
M2 = 0.00 (kN*m)  M1 = 0.00 (kN*m)  Mmid = 0.00 (kN*m)
Case: Cross-section in the middle of the column, Slenderness not taken into account
M0e = 0.6*M02 + 0.4*M01 = 0.00 (kN*m)
M0emin = 0.4*M02
M0 = max(M0e, M0emin)

ea = 0.0 (cm)
Ma = N*ea = 0.00 (kN*m)
MEdmin = 5.32 (kN*m)
M0Ed = max(MEdmin, M0 + Ma) = 5.32 (kN*m)

2.5.2 Reinforcement:

Real (provided) area
Asr = 12.57 (cm²)
Ratio:
ρ = 0.79 %

2.6 Reinforcement:

Main bars (T):
• 4 φ20  l = 11.36  (m)

Transversal reinforcement: (T):
  stirrups:  30 φ8  l = 1.36  (m)

3 Material survey:

• Concrete volume = 1.82  (m³)
• Formwork = 18.24  (m²)

• Steel T
  • Total weight = 128.16  (kG)
  • Density = 70.26  (kG/m³)
  • Average diameter = 14.3  (mm)
  • Reinforcement survey:

<table>
<thead>
<tr>
<th>Diameter</th>
<th>Length</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>40.69</td>
<td>16.06</td>
</tr>
<tr>
<td>20</td>
<td>45.44</td>
<td>112.10</td>
</tr>
</tbody>
</table>
1 Spread footing: F1

1.1 Basic data

1.1.1 Assumptions

- Geotechnic calculations according to: BS 8004
- Concrete calculations according to: EN 1992-1-1:2004 AC:2008
- Shape selection: without limits

1.1.2 Geometry:

\[
\begin{align*}
A &= 0.90 \text{ (m)} & a &= 0.40 \text{ (m)} \\
B &= 0.90 \text{ (m)} & b &= 0.40 \text{ (m)} \\
h1 &= 0.25 \text{ (m)} & e_x &= 0.00 \text{ (m)} \\
h2 &= 0.20 \text{ (m)} & e_y &= 0.00 \text{ (m)} \\
h4 &= 0.05 \text{ (m)}
\end{align*}
\]

\[a' = 40.0 \text{ (cm)}\]
\[b' = 40.0 \text{ (cm)}\]
\[c_{nom1} = 6.0 \text{ (cm)}\]
\[c_{nom2} = 6.0 \text{ (cm)}\]

Cover deviations: Cdev = 1.0(cm), Cdur = 0.0(cm)

1.1.3 Materials

- Concrete: C20/25; Characteristic strength = 20.00 MPa
  Unit weight = 2501.36 (kG/m^3)
  Rectangular stress distribution [3.1.7(3)]

- Longitudinal reinforcement MPa:
  Type Characteristic strength = 500.00
  Ductility class: C
  Horizontal branch of the stress-strain diagram

- Transversal reinforcement MPa:
  Type Characteristic strength = 500.00

- Additional reinforcement: Type Characteristic strength = 500.00
1.1.4 Loads:

**Foundation loads:**

<table>
<thead>
<tr>
<th>Case</th>
<th>Nature</th>
<th>Group</th>
<th>N</th>
<th>Fx</th>
<th>Fy</th>
<th>Mx</th>
<th>My</th>
</tr>
</thead>
<tbody>
<tr>
<td>DL1</td>
<td>dead load(Structural)</td>
<td>64</td>
<td>114.58</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>LL1</td>
<td>live load(Category A)</td>
<td>64</td>
<td>94.48</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>DL1</td>
<td>dead load(Structural)</td>
<td>65</td>
<td>47.76</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>LL1</td>
<td>live load(Category A)</td>
<td>65</td>
<td>32.97</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

**Backfill loads:**

<table>
<thead>
<tr>
<th>Case</th>
<th>Nature</th>
<th>Q1</th>
</tr>
</thead>
</table>

1.1.5 Combination list

1/ 64_SLS : 1.00DL1+1.00LL1
2/ 64_SLS : 1.00DL1
3/ 64_SLS : 1.00DL1+0.80LL1
4/ 65_SLS : 1.00DL1+1.00LL1
5/ 65_SLS : 1.00DL1
6/ 65_SLS : 1.00DL1+0.80LL1
7/* 64_ULS : 1.35DL1+1.50LL1
8/* 64_ULS : 1.35DL1
9/* 64_ULS : 1.00DL1+1.50LL1
10/* 64_ULS : 1.00DL1
11/* 65_ULS : 1.35DL1+1.50LL1
12/* 65_ULS : 1.35DL1
13/* 65_ULS : 1.00DL1+1.50LL1
14/* 65_ULS : 1.00DL1
15/* 64_SLS : 1.00DL1+1.00LL1
16/* 64_SLS : 1.00DL1
17/* 64_SLS : 1.00DL1+0.50LL1
18/* 64_SLS : 1.00DL1+0.30LL1
19/* 65_SLS : 1.00DL1+1.00LL1
20/* 65_SLS : 1.00DL1
21/* 65_SLS : 1.00DL1+0.50LL1
22/* 65_SLS : 1.00DL1+0.30LL1

1.2 Geotechnical design

1.2.1 Assumptions

Foundation design for:
- Capacity
- Rotation
- Sliding
- Sliding with soil pressure considered: none
- Uplift
- Average settlement

1.2.2 Soil:

Soil level: \( N_1 = 0.00 \) (m)
Column pier level: \( N_a = 0.00 \) (m)
Minimum reference level: \( N_r = -0.50 \) (m)
Clay
• Soil level: 0.00 (m)
• Unit weight: 2243.38 (kG/m^3)
• Unit weight of solid: 2753.23 (kG/m^3)
• Internal friction angle: 25.0 (Deg)
• Cohesion: 0.06 (MPa)

1.2.3 Limit states

Stress calculations

Soil type under foundation: not layered
Design combination: 64_SLS : 1.00DL1+1.00LL1
Load factors:
  1.00 * Foundation weight
  1.00 * Soil weight

Calculation results: On the foundation level
Weight of foundation and soil over it: Gr = 8.61 (kN)
Design load:
  Nr = 217.67 (kN)  Mx = -0.00 (kN*m)  My = 0.00 (kN*m)
Soil profile parameters:
  C = 0.00 (MPa)
  φ = 0.0
  γ = 0.00 (kG/m^3)
Stress in soil: 0.27 (MPa)
Design soil pressure 0.30 (MPa)
Safety factor: 1.116 > 1

Uplift

Uplift in SLS
Design combination: 65_SLS : 1.00DL1
Load factors:
  1.00 * Foundation weight
  1.00 * Soil weight
Contact area:
  s = 2.25
  s_{lim} = 1.00

Sliding

Design combination: 65_SLS : 1.00DL1
Load factors:
  1.00 * Foundation weight
  1.00 * Soil weight
Weight of foundation and soil over it: Gr = 8.61 (kN)
Design load:
  Nr = 56.38 (kN)  Mx = -0.00 (kN*m)  My = 0.00 (kN*m)
Equivalent foundation dimensions: A_ = 0.90 (m)  B_ = 0.90 (m)
Sliding area: 0.81 (m^2)
Foundation/soil friction coefficient: tan(φ) = 0.47
Cohesion: C = 0.06 (MPa)
Sliding force value: F = 0.00 (kN)
Value of force preventing foundation sliding:
  On the foundation level: F_{stab} = 74.89 (kN)
Stability for sliding: ∞

Average settlement
Soil type under foundation: not layered

Design combination: **64_SLS : 1.00DL1+1.00LL1**

Load factors:
- 1.00 * Foundation weight
- 1.00 * Soil weight

Weight of foundation and soil over it: \( Gr = 8.61 \) (kN)

Average stress caused by design load: \( q = 0.27 \) (MPa)

Thickness of the actively settling soil: \( z = 2.70 \) (m)

Stress on the level \( z \):
- Additional: \( \sigma_{zd} = 0.01 \) (MPa)
- Caused by soil weight: \( \sigma_{zf} = 0.07 \) (MPa)

Settlement:
- Original: \( s' = 0.2 \) (cm)
- Secondary: \( s'' = 0.0 \) (cm)
- TOTAL: \( S = 0.2 \) (cm) < \( Sadm = 5.0 \) (cm)

Safety factor: 21.29 > 1

### Settlement difference

Design combination: **65_SLS : 1.00DL1+0.80LL1**

Load factors:
- 1.00 * Foundation weight
- 1.00 * Soil weight

Settlement difference: \( S = 0.0 \) (cm) < \( Sadm = 5.0 \) (cm)

Safety factor: \( \infty \)

### Rotation

**About OX axis**

Design combination: **65_SLS : 1.00DL1**

Load factors:
- 1.00 * Foundation weight
- 1.00 * Soil weight

Design load:
- \( Nr = 56.38 \) (kN)
- \( M_x = -0.00 \) (kN*m)
- \( M_y = 0.00 \) (kN*m)

Stability moment: \( M_{stab} = 25.37 \) (kN*m)

Rotation moment: \( M_{renv} = 0.00 \) (kN*m)

Stability for rotation: \( \infty \)

**About OY axis**

Design combination: **65_SLS : 1.00DL1**

Load factors:
- 1.00 * Foundation weight
- 1.00 * Soil weight

Design load:
- \( Nr = 56.38 \) (kN)
- \( M_x = -0.00 \) (kN*m)
- \( M_y = 0.00 \) (kN*m)

Stability moment: \( M_{stab} = 25.37 \) (kN*m)

Rotation moment: \( M_{renv} = 0.00 \) (kN*m)

Stability for rotation: \( \infty \)

### 1.3 RC design

#### 1.3.1 Assumptions
1.3.2 Analysis of punching and shear

Punching

Design combination: 64_ULS : 1.35DL1+1.50LL1
Load factors:
- 1.35 * Foundation weight
- 1.35 * Soil weight

Design load:
- \( N_r = 308.03 \) (kN)
- \( M_x = -0.00 \) (kN*m)
- \( M_y = 0.00 \) (kN*m)

Length of critical circumference: 2.28 (m)

Punching force: 161.37 (kN)
Section effective height: \( h_{eff} = 0.18 \) (m)

Reinforcement ratio: \( \rho = 0.13 \)%
Shear stress: 0.39 (MPa)
Admissible shear stress: 1.48 (MPa)
Safety factor: 3.751 > 1

1.3.3 Required reinforcement

Spread footing:

- Bottom:
  - 64_ULS : 1.35DL1+1.50LL1
  - \( M_y = 15.84 \) (kN*m)
  - \( A_{sx} = 2.34 \) (cm²/m)

  - 64_ULS : 1.35DL1+1.50LL1
  - \( M_x = 15.84 \) (kN*m)
  - \( A_{sy} = 2.34 \) (cm²/m)

  \( A_{s_{min}} = 2.34 \) (cm²/m)

- Top:
  - \( A'_{sx} = 0.00 \) (cm²/m)
  - \( A'_{sy} = 0.00 \) (cm²/m)

  \( A_{s_{min}} = 0.00 \) (cm²/m)

Column pier:

Longitudinal reinforcement:
- \( A = 3.20 \) (cm²)  \( A_{min.} = 3.20 \) (cm²)
- \( A = 2 \cdot (A_{sx} + A_{sy}) \)
- \( A_{sx} = 0.60 \) (cm²)  \( A_{sy} = 1.00 \) (cm²)

1.3.4 Provided reinforcement

Spread footing:

Bottom:
- Along X axis:
  - Length: \( l = 1.11 \) (m)
  - Eccentricity: \( e = 1^*0.36 + 4^*0.18 \)
Pier

Longitudinal reinforcement
Along X axis:
\[
\begin{array}{c|c|c}
5 & 8 & l = 1.11 \text{ (m)} \quad e = 1^\ast -0.36 + 4^\ast 0.18 \\
\end{array}
\]
Along Y axis:
\[
\begin{array}{c|c|c}
2 & 12 & l = 1.22 \text{ (m)} \quad e = 1^\ast -0.11 + 1^\ast 0.21 \\
\end{array}
\]

Transversal reinforcement
\[
\begin{array}{c|c|c}
2 & 12 & l = 1.27 \text{ (m)} \quad e = 1^\ast -0.11 + 1^\ast 0.21 \\
\end{array}
\]

Material survey:

- Concrete volume \(= 0.23 \text{ (m}^3\)
- Formwork \(= 1.22 \text{ (m}^2\)
- Steel
  - Total weight \(= 10.23 \text{ (kG)}\)
  - Density \(= 43.64 \text{ (kG/m}^3\)
  - Average diameter \(= 9.0 \text{ (mm)}\)
- Survey according to diameters:

<table>
<thead>
<tr>
<th>Diameter</th>
<th>Length (m)</th>
<th>Weight (kG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>14.71</td>
<td>5.80</td>
</tr>
<tr>
<td>12</td>
<td>4.99</td>
<td>4.43</td>
</tr>
</tbody>
</table>