Spread footing verification

Input data

Project
Task : Preliminary design of shallow foundation
Part : Centric spread footing
Customer : CTU
Author : Bc. Yosufi Mohammad Fayez
Date : 20.12.2019

Settings
Standard - safety factors
Materials and standards
Concrete structures : EN 1992-1-1 (EC2)
Coefficients EN 1992-1-1 : standard

Settlement
Analysis method : Analysis using oedometric modulus
Restriction of influence zone : by percentage of Sigma,Or
Coeff. of restriction of influence zone : 10,0 [%]

Spread Footing
Analysis for drained conditions : Standard approach
Analysis of uplift : Standard
Allowable eccentricity : 0,333
Verification methodology : Safety factors (ASD)

Safety factors
Permanent design situation
Safety factor for vertical bearing capacity :

SF\textsubscript{V} = 1,50 [-]

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Safety factors

Permanent design situation

Safety factor for sliding resistance: \[ SF_h = 1.50 \]

Basic soil parameters

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Pattern</th>
<th>( \phi_{ef} ) [°]</th>
<th>( c_{ef} ) [kPa]</th>
<th>( \gamma ) [kN/m³]</th>
<th>( \gamma_{su} ) [kN/m³]</th>
<th>( \delta ) [°]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Poorly graded sand (SP), medium dense</td>
<td><img src="image1" alt="Pattern" /></td>
<td>33,50</td>
<td>0,00</td>
<td>18,50</td>
<td>8,50</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Well graded gravel (GW), medium dense</td>
<td><img src="image2" alt="Pattern" /></td>
<td>38,50</td>
<td>0,00</td>
<td>21,00</td>
<td>11,00</td>
<td></td>
</tr>
</tbody>
</table>

All soils are considered as cohesionless for at rest pressure analysis.

Soil parameters

**Poorly graded sand (SP), medium dense**

- Unit weight: \( \gamma = 18.50 \text{ kN/m}^3 \)
- Angle of internal friction: \( \phi_{ef} = 33.50^\circ \)
- Cohesion of soil: \( c_{ef} = 0.00 \text{ kPa} \)
- Oedometric modulus: \( E_{oed} = 32.00 \text{ MPa} \)
- Saturated unit weight: \( \gamma_{sat} = 18.50 \text{ kN/m}^3 \)

**Well graded gravel (GW), medium dense**

- Unit weight: \( \gamma = 21.00 \text{ kN/m}^3 \)
- Angle of internal friction: \( \phi_{ef} = 38.50^\circ \)
- Cohesion of soil: \( c_{ef} = 0.00 \text{ kPa} \)
- Oedometric modulus: \( E_{oed} = 355.50 \text{ MPa} \)
- Saturated unit weight: \( \gamma_{sat} = 21.00 \text{ kN/m}^3 \)

Foundation

**Foundation type: centric spread footing**

- Depth from original ground surface: \( h_z = 4.40 \text{ m} \)
- Depth of footing bottom: \( d = 0.00 \text{ m} \)
- Foundation thickness: \( t = 1.00 \text{ m} \)
- Incl. of finished grade: \( s_1 = 0.00^\circ \)
- Incl. of footing bottom: \( s_2 = 0.00^\circ \)

- Unit weight of soil above foundation = 20.00 kN/m³

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### Geometry of structure

**Foundation type: centric spread footing**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spread footing length</td>
<td>$x = 2.00$ m</td>
</tr>
<tr>
<td>Spread footing width</td>
<td>$y = 2.00$ m</td>
</tr>
</tbody>
</table>

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Column width in the direction of $x$ $c_x = 0.30$ m
Column width in the direction of $y$ $c_y = 0.30$ m
Spread footing volume $= 4.00$ m$^3$

### Material of structure

Unit weight $\gamma = 23.00$ kN/m$^3$
Analysis of concrete structures carried out according to the standard EN 1992-1-1 (EC2).

**Concrete : C 30/37**
- Cylinder compressive strength $f_{ck} = 30.00$ MPa
- Tensile strength $f_{ctm} = 2.90$ MPa
- Elasticity modulus $E_{cm} = 33000.00$ MPa

**Longitudinal steel : B500**
- Yield strength $f_{yk} = 500.00$ MPa

**Transverse steel : B500**
- Yield strength $f_{yk} = 500.00$ MPa

### Geological profile and assigned soils

<table>
<thead>
<tr>
<th>No.</th>
<th>Thickness of layer [m]</th>
<th>Depth [m]</th>
<th>Altitude [m]</th>
<th>Assigned soil</th>
<th>Pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.40</td>
<td>0.00 .. 4.40</td>
<td>4.40 .. 0.00</td>
<td>Poorly graded sand (SP), medium dense</td>
<td><img src="image1.png" alt="Pattern" /></td>
</tr>
<tr>
<td>2</td>
<td>-</td>
<td>4.40 .. $\infty$</td>
<td>0.00 .. -</td>
<td>Well graded gravel (GW), medium dense</td>
<td><img src="image2.png" alt="Pattern" /></td>
</tr>
</tbody>
</table>

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Name: Load - LC

Stage - analysis: 1 - 0

Ground water table

The ground water table is at a depth of 12,00 m from the original terrain.
Global settings
Type of analysis: analysis for drained conditions

Settings of the stage of construction
Design situation: permanent

Verification No. 1
Load case verification

<table>
<thead>
<tr>
<th>Name</th>
<th>( e_x ) [m]</th>
<th>( e_y ) [m]</th>
<th>( \sigma ) [kPa]</th>
<th>( R_d ) [kPa]</th>
<th>Utilization [%]</th>
<th>Is satisfactory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load No. 1</td>
<td>0.00</td>
<td>-0.01</td>
<td>528.72</td>
<td>890.81</td>
<td>89.03</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Analysis carried out with automatic selection of the most unfavourable load cases.

Computed weight of spread footing \( G = 92.00 \) kN
Computed weight of overburden \( Z = 0.00 \) kN

Vertical bearing capacity check
Shape of contact stress: rectangle
Most unfavorable load case No. 1. (Load No. 1)

Parameters of slip surface below foundation:
Depth of slip surface \( z_{sp} = 3.80 \) m
Length of slip surface \( l_{sp} = 12.52 \) m

Design bearing capacity of found. soil \( R_d = 890.81 \) kPa
Extreme contact stress \( \sigma = 528.72 \) kPa

Factor of safety = 1,68 > 1,50

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Bearing capacity in the vertical direction is SATISFACTORY

Verification of load eccentricity
Max. eccentricity in direction of base length \( e_x = 0,001 < 0,333 \)
Max. eccentricity in direction of base width \( e_y = 0,003 < 0,333 \)
Max. overall eccentricity \( e_t = 0,003 < 0,333 \)

Eccentricity of load is SATISFACTORY

Horizontal bearing capacity check

Most unfavorable load case No. 1. (Load No. 1)
Earth resistance: at rest
Design magnitude of earth resistance \( S_{pd} = 0,00 \) kN
Horizontal bearing capacity \( R_{dh} = 1667,82 \) kN
Extreme horizontal force \( H = 5,83 \) kN

Factor of safety = 286,03 > 1,50
Bearing capacity in the horizontal direction is SATISFACTORY

Bearing capacity of foundation is SATISFACTORY
Verification No. 1

Settlement and rotation of foundation - input data

Analysis carried out with automatic selection of the most unfavourable load cases.
Analysis carried out with accounting for coefficient $k_1$ (influence of foundation depth).
Stress at the footing bottom considered from the finished grade.

Computed weight of spread footing $G = 92,00 \text{ kN}$
Computed weight of overburden $Z = 0,00 \text{ kN}$
Settlement of mid point of edge $x \cdot 1 = 1,3 \text{ mm}$
Settlement of mid point of edge $x \cdot 2 = 1,3 \text{ mm}$
Settlement of mid point of edge $y \cdot 1 = 1,3 \text{ mm}$
Settlement of mid point of edge $y \cdot 2 = 1,3 \text{ mm}$
Settlement of foundation center point = $2,1 \text{ mm}$
Settlement of characteristic point = $1,5 \text{ mm}$

(1-max.compressed edge; 2-min.compressed edge)

Settlement and rotation of foundation - results

Foundation stiffness:
Computed weighted average modulus of deformation $E_{\text{def}} = 319,95 \text{ MPa}$
Foundation in the longitudinal direction is rigid ($k=12,89$)
Foundation in the direction of width is rigid ($k=12,89$)

Verification of load eccentricity
Max. eccentricity in direction of base length $e_x = 0,001<0,333$
Max. eccentricity in direction of base width $e_y = 0,003<0,333$
Max. overall eccentricity $e_t = 0,003<0,333$

Eccentricity of load is SATISFACTORY
**Overall settlement and rotation of foundation:**

Foundation settlement = 1,5 mm  
Depth of influence zone = 5,69 m  
Rotation in direction of x = 0,004 (tan*1000); (2,3E-04 °)  
Rotation in direction of y = 0,010 (tan*1000); (5,9E-04 °)

<table>
<thead>
<tr>
<th>Name : Settlement</th>
<th>Stage - analysis : 1 - 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>OG</td>
<td>FG</td>
</tr>
<tr>
<td>5,69</td>
<td>5,69</td>
</tr>
<tr>
<td>Sigma,z</td>
<td>Sigma,or</td>
</tr>
</tbody>
</table>

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Dimensioning No. 1

Analysis carried out with automatic selection of the most unfavourable load cases.

Verification of longitudinal reinforcement of foundation in the direction of x
6 prof. 25,0 mm, cover 50,0 mm
Cross-section width = 2,00 m
Cross-section depth = 1,00 m
Reinforcement ratio $\rho = 0,16 \% > 0,15 \% = \rho_{\min}$
Position of neutral axis $x = 0,04 m < 0,58 m = x_{\max}$
Ultimate moment $M_{Rd} = 1180,01 kNm > 363,96 kNm = M_{Ed}$

Cross-section is SATISFACTORY.

Verification of longitudinal reinforcement of foundation in the direction of y
6 prof. 25,0 mm, cover 50,0 mm
Cross-section width = 2,00 m
Cross-section depth = 1,00 m
Reinforcement ratio $\rho = 0,16 \% > 0,15 \% = \rho_{\min}$
Position of neutral axis $x = 0,04 m < 0,58 m = x_{\max}$
Ultimate moment $M_{Rd} = 1180,01 kNm > 366,93 kNm = M_{Ed}$

Cross-section is SATISFACTORY.

Spread footing for punching shear failure check
Shear reinforcement of critical cross section
2 prof. 10,0 mm
Angle of slope = 45,00 °
Column normal force = 2004,74 kN
**Maximum resistance at the column perimeter**

Force transferred into found. soil \(= 45,11 \text{ kN}\)

Force transferred by shear strength of foundation \(= 1959,63 \text{ kN}\)

Considered column perimeter \(u_0 = 1,20 \text{ m}\)

Shear resistance at the column perimeter \(v_{Ed,\text{max}} = 1,81 \text{ MPa}\)

Resistance at the column perimeter \(v_{Rd,\text{max}} = 4,22 \text{ MPa}\)

**Critical section with shear reinforcement**

Force transferred into found. soil \(= 672,83 \text{ kN}\)

Force transferred by shear strength of foundation \(= 1331,91 \text{ kN}\)

Distance of section from the column \(= 0,47 \text{ m}\)

Section perimeter \(u = 4,14 \text{ m}\)

Shear stress at section \(v_{Ed} = 0,35 \text{ MPa}\)

Reinforced section shear resistance \(v_{Rd,cs} = 1,36 \text{ MPa}\)

\(v_{Ed} < v_{Rd,cs} \Rightarrow \text{SECTION IS SATISFACTORY}\)

**Spread footing for punching shear is SATISFACTORY**

### Name : Dimensioning  
### Stage - analysis : 1 - 1

**Plan:**

- Section A-A: 6 prof. 25,0 mm, length 1900mm, concrete cover 50mm
- Section B-B: 6 prof. 25,0 mm, length 1900mm, concrete cover 50mm
Name: Dimensioning

Plan:

Section A-A:
6 prof. 25,0 mm
length 1900mm, concrete cover 50mm

Section B-B:
6 prof. 25,0 mm
length 1900mm, concrete cover 50mm

Punching shear - critical section:

Loading area transferred by RC through shear area: 9,00E-02m²
critical section length: 1,20m
checked sections